NASA Research and Education Network
NREN Workshop II White Paper

"Tomorrow's Networking Applications Today"

March 1998

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1. SUMMARY

The Second Annual High Performance Computing and Communications/NASA Research and Education (HPCC/NREN) Workshop was held September 15 to 17, 1997, at NASA Ames Research Center at Moffett Field, California. Workshop II was attended by over 100 scientists and networking experts. It continued the effort begun at the first NREN Workshop held in May 1996 to share information and experience about NASA's advanced networking technologies and applications and to gain user feedback on high-performance networking applications that drive the research network and network research.

Five highly visible applications were demonstrated to illustrate how high-performance, high-speed networks can facilitate and enhance science and research in a variety of fields. The demonstrations were well received and included the Virtual Simulation Laboratory (VLAB), Mars Pathfinder, Nomad Rover, Echocardiography, and the Distributed Image SpreadSheet.

Participants had an opportunity to join one of six affinity working groups: Advanced Aerospace Design, Astrobiology, Astrophysics, Earth Science, Space Exploration, and Telemedicine. Each of these working groups produced a short white paper identifying requirements for their discipline. The affinity groups brought together discipline scientists and networking engineers to look into the near future to determine what applications could benefit from a high-performance network—and indeed could not be performed without such a network—and to prioritize those applications as a basis for planning. Groups were provided with a suggested “roadmap” to guide discussions, and a suggested outline for their white paper.

Initial results of the workshop reinforced the need for a strong program in advanced networking for NASA missions and applications. Among the future applications research needs that were identified were 3-D collaborations, digital libraries, distributed computing, image processing, scientific visualization, simulation, and virtual environments.

The NREN staff would like to thank all of the participants for their time and valuable input, and all of the many support personnel who made the Workshop possible.

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2. INTRODUCTION

NREN is enabling revolutionary applications by accelerating networking technology development for aeronautics and space. NREN envisions a future in which aerospace engineers will revolutionize aircraft design by remotely controlling wind tunnels on their desktops, astronauts and engineers will train together in realistic simulations of space flight, medical researchers will safely monitor and treat humans in space from the Earth, Earth scientists from all over the country will develop climate models that allow us to predict and respond to environmental events such as floods, and space scientists will chart the evolution of the universe.

Networking technology is extremely important to NASA. It is a major force multiplier in countless aerospace-related fields and will play an even greater role in the future. NREN will demonstrate future NASA applications and enable discoveries currently impossible. NREN faces significant networking challenges in accomplishing its mission. Scientific demands for speed, throughput, reliability and security have grown over the last decade and continue to grow exponentially. The community needs better ways to exchange information and knowledge with far less delay and risk. These increasing scientific demands have been the drivers in accelerating the development of network technology to demonstrate tomorrow's network applications today.

To address these challenges, NREN serves as NASA's cornerstone of collaboration in the interagency Next Generation Internet (NGI) program. NGI is developing technology that charts a course for future networking applications, interoperates with the existing Internet, and can be readily transferred to commercial networks. Without this accelerated development, these improvements may not be available for 15 to 20 years.

Critical agency missions depend on information technologies—for example, NASA's Earth Science enterprise will have to move petabytes of information (trillions of bits) in the coming years, and revolutionizing air travel will require reducing the aircraft design life cycle. NREN supports the High Performance Computing and Communications Program community, NASA missions (Mission to Planet Earth, advanced aerospace design, telemedicine, astrobiology, astrophysics, remote operations, and simulations), and many other important national goals. NREN currently connects five NASA centers at speeds of 155 Mb/s and is expanding in both speed, function, reliability, and reach.

NREN will provide both a high performance network application testbed and a network research testbed for the NASA community and its partners. These testbeds exist at the various NASA centers now and will be interconnected via NREN, thus providing virtual testbeds and harnessing the expertise distributed throughout NASA.

3. PURPOSE AND OBJECTIVES

The purpose of the Workshop was to further NREN's mission which is to lead the agency in the exploration and development of innovative end-to-end internetworking solutions that enable revolutionary applications for NASA missions and the Nation. The six affinity groups—Advanced Aerospace Design, Astrobiology, Astrophysics, Earth Sciences, Space Exploration, and Telemedicine—share requirements for such capabilities as distributed computing, remote operation, digital libraries, collaboratories, and privacy and security.

The objectives for the Affinity Groups were to:

- Think "out of the box" to identify applications which will improve mission success using advanced networking technologies
- Gather data on applications requiring high performance networking technologies
- Collaborate to prioritize these needs through consensus and set the top priorities in next five years
- Identify needs common to other affinity groups (collaborative tools, distributed computing, etc.) and report to the NREN team

4. INTRODUCTORY REMARKS

4.1 Bill Berry, Acting Deputy Director the Center

Bill Berry, representing Director Henry McDonald, welcomed the participants to Ames Research Center (ARC). Berry spoke of the transition at ARC away from such traditional roles as wind tunnel research to Information Technology (IT). ARC has been building its management staff in IT, he continued, and this Workshop will help facilitate IT at the Center.

4.2 Steve Zornetzer, Director, Information Systems Directorate

Steve Zornetzer, Director of the Information Systems Directorate at ARC, presented a broad overview of ARC activities in regard to Information Technology. One year ago, NASA Administrator Daniel Golden designated ARC as the Center of Excellence (COE) in IT, stating that ". . . the future of space is in IT." Space missions will rely on IT beyond what we are presently offering. With IT as a main focus, ARC's areas of responsibilities include the COE role, Lead Center missions in aviation operations systems and astrobiology, and various Lead Center responsibilities. "The Information System's mission here at ARC is simple, but hard to deliver," said Zornetzer. "It is to provide access to knowledge that enables understanding and discovery. IT is key to future capabilities such as collaborative computing."

In a slide depicting Information-Based Advisory Systems and Autonomous Systems, Zornetzer showed a central cloud, with design, science understanding, spacecraft autonomy, and air and space operations as points on the circumference. He termed these "cognitive prostheses," something that makes you think, perform, and understand better. Networking is a key component to success and to the future of these activities.

4.3 William Feiereisen, HPCC Program Manager

William Feiereisen, HPCC Program Manager, spoke on the High Performance Computing and Communications Program. Feiereisen gave an overview of HPCCP's national goals and of NASA's HPCC Program goals. Touching on the history of HPCC, he said that agreement was reached on the HPCC federal program in 1991. It was to be a concerted science and engineering "supercomputing" program to bring TeraFLOPS (1000 x 1 billion floating point operations per second) in five years instead of ten. Each of eight federal agencies which received funding under the program was free to structure a computing technology program around agency "mission needs." NASA's needs were "big simulations" in the aerosciences and in Earth and space sciences. Recognizing that speed and memory capacity would only be met with parallel machines, the program began its "Quest for TeraFLOPS" by the year 2000.

NASA's mission needs included large multidisciplinary aerospace simulations, large astrophysics simulations, and global climate modeling. These became the "Grand Challenges," the applications driving computing technology. Feiereisen then described the five projects of NASA's HPCC Program:

- Computational Aerosciences (CAS) concentrates on aerospace design utilizing distributed heterogeneous computing (coupled machines located in widely distributed areas "stitched together" by networks).
- Earth and Space Sciences (ESS) emphasizes global climate modeling to address such questions as, "Is climate warming or cooling?" ESS studies are oriented towards TeraFLOPS and expect to be able to answer that question in six years.
- Remote Exploration and Experimentation (REE) addresses the need for high performance computers onboard spacecraft. The objective is to allow more, smaller spacecraft by providing autonomous, low-power computers built on parallel computing to take the load off of the infrastructure.
- Learning Technologies Project (LTP), the follow-on to the Information Infrastructure Technology and Applications (IITA) program, has shifted emphasis from distribution of material via the Internet to an educational program. It will maintain the connections to the K-12 organizations that it has built.
- NASA Research and Education Network (NREN), has become integral to the support of the Grand Challenges. It provides the "Information Power Grid" supporting nodes of equal value that include such activities as computing, collaborative technologies, processing of large datasets, wind tunnel testing and simulations, and electron microscopy.

In summary, NASA's HPCC Program accelerates the development, application, and transfer of high-performance technologies to meet the engineering and science needs of the U.S. aeronautics, Earth science, and space science communities, and the implementation of a National Information Infrastructure.

4.4 Christine Falsetti, NREN Project Manager

Christine Falsetti presented an overview of NREN in historical perspective to show the direction we are heading. The Internet was formed 30 years ago by the Defense

Advanced Research Projects Agency (DARPA) to solve a particular problem—to protect its supercomputers on campuses where Viet Nam protests were being held. “How to provide access to supercomputers for researchers and have it secure.” In 1970, the University of Illinois sent ARC its Illiac computer to protect it. It was connected to 1000 sites worldwide. Two men, Bob Kahn and Vint Cerf, founders of the Internet, developed remote login (Telnet), email, and file transfer. In the 1980s, a TCP/IP network, ARPAnet, connected more nodes over the network, including the Department of Energy and NASA.

Today the Internet is used in vastly different ways; our concern now is with the applications of the future. A five-minute video highlighting the work NREN has accomplished was shown to start Workshop participants thinking about applications of the future.

Falsetti said that ARC is playing a pathfinding role in developing the Next Generation Internet (NGI). The NREN project and its existing network is the basis for implementation of the NASA NGI plan. NREN sees networking as three-dimensional, concerned not just with capacity (speed and distance) , but also with capability (policy and intelligence), and the next generation of network applications (collaborative communications, virtual institutions, wind tunnels online, and the Information Power Grid).

One of NREN’s key goals is to support demonstrations of next generation applications requiring advanced networking technologies. The objectives are to improve distributed application performance over networks, to act as a catalyst in the integration of high performance networking technology, to provide nationwide prototypes for hybrid networks (terrestrial, satellite, wireless, and wireline communications), and to ensure that different types of networks work together as a cohesive system.

What would be the impact if there were no NREN program? Falsetti pointed out that the commercial sector is on a different applications curve than the science community. Without the NREN program, it would take a decade or longer to reach the level of complex applications and additional capabilities that NREN is pushing for.

What is NREN looking for? Falsetti defined the different classifications of and what each incorporates. NREN is a Class 2 research network, “leading-edge, advanced application enabled;” other such networks are the Energy Sciences network, the National Science Foundation’s vBNS, and the Defense Research and Engineering Network. Discussing the Internal Technology Transfer model, she said that the focus of the workshop is on testbeds, experimental networks, and application demonstrations. These technologies are eventually transferred to operational networks such as the NASA Integrated Services Network (NISN).

Falsetti next reviewed the map of the proposed NGI architecture (a Class 2 network), the network technology services, and the six key applications that serve as the basis for the Workshop Affinity Groups. She then discussed the objectives for the Affinity Groups and reviewed the roles of the various group members.

4.5 Debra Bailey, NREN Applications Manager

At the start of Day 2, Debra Bailey, NREN Applications Manager, discussed the area of applications and the direction NREN is taking. She said that the Workshop is focused on the participants' application needs, and emphasized that NREN needs to understand what they want to do so that it can match its activities to what the scientists are doing. After the Workshop, NREN will work with the participants to match their needs to network solutions.

Bailey discussed the five top applications that have been successfully completed, and mentioned two additional application testbeds in which NREN played a part [Asynchronous Transfer Mode (ATM) Research and Industrial Enterprise Study (ARIES) and Data Assimilation Office (DAO) at GSFC] and encouraged people to look at the NREN Web Applications inventory.

Bailey then went over the proposal solicitation process and the process flow.

5. DEMONSTRATION PRESENTATIONS

5.1 Telemedicine

Dr. Jim Thomas of the Cardiovascular Imaging Center at the Cleveland Clinic Foundation in Ohio discussed the demonstration titled "Real-Time, Interactive Echocardiography Over High Speed Digital Networks: An NREN Experiment."

Thomas discussed echocardiography and the need for digital transmission to allow remote consultation both on Earth and in space where digital transmission will be essential both for science and crew health. He showed a typical 2-D image (color Doppler) that quantifies blood flow, and stated that we are heading towards 3-D images in the future. The power of this technology is that it is also applicable to other areas of medicine such as the brain.

The purpose of the demonstration was to establish the feasibility of real-time transmission of echocardiograms using MPEG-2 and ATM, and to determine the necessary bandwidth for diagnostic image quality. His studies showed that all digital media was preferable to digitized video tape images.

NREN provided the high bandwidth that was essential for full motion, full color ultrasound which generates 30 Megabytes of data per second. A 20:1 JPEG compression has been validated, but the data rate is still enormous. ATM looks attractive for long-distance, high-speed transmission, but so far they have little experience with it.

In conclusion, Thomas said that the old standard of video is no longer acceptable compared to digital transmission. "Real" telemedicine will be accomplished on the International Space Station (ISS) in the year 2000, but the bandwidth available on ISS is relatively low (50 Mbps). 3-D echocardiography work is progressing, and he plans to use NREN again at the 50 MByte level. The next step will be 3-D visualizations of CT and MRI. "The need for telemedicine in space will grow exponentially," he said.

5.2 Virtual Simulation Laboratory (VLAB)

Steve Cowart of the Ames Virtual Simulation Laboratory (VLAB) described the Ames Vertical Motion Simulator (VMS) facility as the largest motion basis in the world (60' tall, 40' wide). Researchers come to the Simulation Lab (SimLab) of the VMS for Shuttle, High Speed Transport, and Tilt Rotor simulations.

The goal of VLAB was to put remote researchers into the lab which it accomplished by extending access to Johnson Space Center (JSC) 2000 miles away. VLAB presents a virtual environment that permits remote, interactive participation with the VMS SimLab via NREN.

Simulation plays a central role in the aircraft design cycle, and VLAB is a tool to accomplish that. VLAB was planned to be as “immersive” as possible for the researchers and engineers. For example, personnel in the lab are tracked with wireless headsets, a shoulder tap opens up wireless communications, a joy stick lets a person move about and locate themselves anywhere in the building to see in real time what the cab is doing.

Remote researchers can click on icons and bring up screens, and they can see what the pilot sees in the cab. They can also bring up strip charts, a “better than reality” tool that lets them stay where they are and see all of the screens they want. The image generator provides in high fidelity what the pilots see as they come in for a landing. An End of Run display provides important information to the Principal Investigators.

MPEG was used to allow the user to see what the pilot saw. Images were digitized, compressed, sent to JSC, and uncompressed. Videoconferencing was the slowest part, but all other data (Optivision prototype encoder/decoder) was incredibly fast.

NREN was critical to the success of VLAB. It provided a 145-Mbps line with uninterrupted service to JSC. Videoconferencing, service, throughput, out-the-window scenes, all were excellent.

In summary, the VLAB tool was deemed very useful. Remote and local investigators collaborated with colleagues at JSC to solve numerous problems. In the future, VLAB will add an additional personal “feel” and will broaden simulations to wind tunnels and other applications.

See URL: http://www.simlabs.arc.nasa.gov/vlab

5.3 Distributed Image SpreadSheet

Dr. K. Palaniappan of the University of Missouri in Columbia, Missouri, presented slides on work he and his colleague, Dr. Fritz Hasler of Goddard Space Flight Center, are doing on “Networked Visanalysis Using the Distributed Interactive Image SpreadSheet,” opening his talk with a video of Hurricanes Luis and Andrew showing nature’s fury.

In discussing his visualization work, he stated that traditional spread sheet paradigms are being extended for managing and visualizing, analyzing and intercomparing, and for distributed network access to data. The project includes the analysis of huge multisource, multispectral, time varying datasets (e.g., EOS); organization of huge datasets in a 3-D cell matrix; synchronized browsing of dense datasets; 3-D model simulations; and coordinated formula evaluation.

The motivation and purpose behind the Interactive Image SpreadSheet is to provide access to terabyte Mission To Planet Earth (MTPE) archives, remote Earth Observing System (EOS) scientists, distributed tools and specialized hardware, and metacomputing resources. The spreadsheets provide both 2-D and 3-D images, each of which is a dataset. Networked visanalysis requires high performance networking such as that provided by NREN to provide for the bandwidth, latency, data, collaboration, and video elements involved.

Scientists maintain a history of thousands of these data sets. [Twenty five years of Geostationary Orbiting Satellite System (GOES) data are archived at the Univ. of Wisconsin.] Data are being collected at the rate of 1 to 2 terabytes per day, and spreadsheets serve as tools in analyzing the huge amounts of data. There is a tremendous need to provide geophysical data over the network for scientific analysis. Public outreach is also very important—some of the data sets are available to NASA Select TV, to other TV channels, and for Web access from a server at Goddard Space Flight Center (GSFC).

Distributed Image SpreadSheets have many benefits: they provide a single environment for visualization, analysis and collaboration; they provide the ability to access 2-D and 3-D time varying datasets; and they allow organization of large volumes of datasets without replication. In the future, users will be able to seamlessly access multiple data archives from their desktops.

5.4 Nomad Rover

Dr. David Wettergreen of the Ames Intelligent Mechanisms Group presented slides on the Nomad rover project. This project was a collaboration between Carnegie Mellon University and Ames Research Center to develop and demonstrate robots for long-distance, long-duration robotic planetary exploration.

The robot Nomad navigated 215 kilometers across the Atacama Desert of Northern Chile in June and July 1997 under the guidance of operators in North America. Nomad communicated via satellite and NREN to scientists and students in Pennsylvania and California, sending live telemetry and imagery of its surroundings.

The project involved several objectives. Technical objectives were to demonstrate the movement, communications and control of the rover in rugged circumstances; to validate the chassis and antennas; and to operate the rover entirely under remote control from the U.S. with simulated time delays to mirror Mars-like guidance. Scientific objectives were to validate panospheric imagery and retinal resolution stereo imagery for remote geology, and to simulate Mars sample collection, Lunar “geology on the fly,” and Antarctic meteorite search missions. Outreach objectives were to create a display of visual information that enables observers to quickly comprehend Nomad’s surroundings, and to enable people at widely distributed sites to simultaneously observe live imagery and participate in the exploration.

NREN was used to transmit robot telemetry and panospheric still images at a sustained rate of 2 Mbps with near zero packet loss, 12 hours per day for 45 days. Imagery from the panospheric camera was relayed from the site to a satellite, and from there to North America. NREN provided reliable transmission from Goddard to Ames for the continuous communications that were required over a long period of time. Existing networks were unable to accommodate demands of this magnitude.

The Nomad project is advancing technology in robot mechanisms, communication, imagery, and control. Expeditions are being planned to Antarctica and Greenland.

5.5 Mars Pathfinder

Dr. Carol Stoker of Ames Research Center presented slides on Virtual Reality for the Mars Pathfinder mission.

The Pathfinder team at Ames invented a new type of map—the 3-D, interactive virtual environment model (MarsMap) that was used for rover operations and science analysis which will be critical in future explorations. Pathfinder used a stationary lander camera (IMP—Image Mars Pathfinder) to provide a reference scene for rover operations. The Virtual Reality model made from IMP images provided Pathfinder operations with a unique tool for understanding the Martian environment. One can “fly around” in 3-D, and other images and data can be projected into the model.

Raw stereo IMP images were transmitted to Ames where terrain models were created using Ames computers. The models were then shipped back to the Jet Propulsion Laboratory (JPL) for display. This procedure required rapid turn-around (two minutes per image pair, and around one hour for a complete panorama), and NREN provided the high speed network link between Ames and JPL. The project required high reliability, especially during the extremely high network traffic period of the mission (350 million Internet hits on Pathfinder Web sites at JPL).

The network connection was seamless; it allowed the “virtual” team at Ames to work as if they were in the next room and proved that high speed networking can allow distributed teams to work as effectively as if collocated. Future missions will require greater use of distributed operations by teams linked by the Internet.

6. CLOSING REMARKS

Bessie Whitaker, NREN Deputy Project Manager, thanked the participants for attending the Workshop and for their valuable contributions to its success. Whitaker said that NREN Workshop 3 is planned for August 1998. Addressing the “Next Step,” she said that we are at present in the data gathering stage and that the NREN team will put together a White Paper summarizing the recommendations of the various Affinity Groups. The draft paper will be distributed by mid-October to solicit comments. Feedback will be requested by mid-November for incorporation in the final paper.

Following this Workshop, the NREN team will hold an internal workshop to determine the technical support required to meet the needs identified in Workshop II. The process will be an ongoing, iterative cycle that will continue to reassess the various applications, priorities, and solutions needed to support the Grand Challenges.

Affinity group leaders then presented summaries of their activities to the Workshop.

7. AFFINITY GROUP SUMMARIES AND RECOMMENDATIONS

7.1 <u>Advanced Aerospace Design</u> Affinity Group White Paper

7.1.1 Summary

Specific aerospace applications identified in this paper reflect emerging trends or desires that clearly impact the aerospace industry and are difficult, if not impossible, to accomplish without significant changes in the capabilities available via networking and other technologies. Emphasis was placed on applications that focus on the vehicle design process since this is an area in which NASA could have a strong effect, and one which can also affect cost and design time. These applications include design environments, virtual facilities, and physics-based deep analysis. Functional network capabilities explored the human aspect, involving communication, conferencing, visualization, and distributed resources. An agile aerospace design process will impact jobs and competition and will be applicable to other industries besides aircraft.

7.1.2 Introduction

The 1997 NASA Research and Education Network (NREN) Workshop was motivated by two major goals:

1) To demonstrate to the participants the successes of the prior year in the application of advanced networking to a variety of science and medical applications, and

2) To solicit genuine creative thought amongst both the application scientists and networking attendees as to the directions advanced networking must take if it is to satisfy their future needs.

While the Advanced Aerospace Design (AAD) Affinity Group acknowledged in advance the difficulty and uncertainty of trying to capture and sort the ideas from a limited group about such a broad subject and the constraint of time on the creative brainstorming process, the group feels comfortable with the ideas presented. It hopes that refinement of the proposed suggestions will take place once the other affinity groups have an opportunity to air their thoughts, and as others become involved with NREN, either because of operational necessity or as part of the information dissemination that will follow the workshop. This white paper is a summary of the discussions in the Advanced Aerospace Design (AAD) Affinity Group.

The AAD group of twelve was composed of aerospace applications designers in both airfoil and propulsion, an industry representative, computational scientists, and networking personnel. The participants are listed in Appendix A. After significant discussion and able direction from both the group chair and meeting facilitator, the group chose to focus their efforts on the following:

- <u>Specific aerospace applications</u>,
- <u>Network capabilities</u>, and
- <u>Network descriptors</u>.

In each category, the thoughts were ranked and then presented at the plenary session of the workshop. The slides from that presentation are shown in appendix B. The rest of the white paper is an expansion and explanation of the information summarized in the presentation shown in appendix B.

7.1.3 Specific Aerospace Applications

The specific aerospace applications identified are emerging trends or desires that clearly impact the aerospace industry and are difficult, if not impossible, to accomplish without significant changes in the capabilities available via networking and other technologies. These examples attempt to bring into focus the direction of the aerospace industry without significant thought as to what the networking industry would be required to do or how the networking industry would accomplish these goals.

Significant emphasis was placed on aerospace applications that focus on the vehicle design process, since it is an area where it was felt NASA could have a generally strong effect, and also an area where significant shifts in vehicle cost and/or design time can take place due to the applications' role in setting overall design parameters. The applications that were felt to be the most significant were design environments, virtual facilities, and physics-based deep analysis.

7.1.3.1 Design Environments

- AST High Lift,
- Helicopter Design,
- Advanced Shuttle Design,
- Engine Design,
- General Aviation Design, and
- 24-hour Multipartner Design

These applications were felt to be very demanding of both computational and networking environments of today and to continue to be demanding in the future. In addition, one member of the group identified the desire on the part of industry to move to multipartner 24-hour design where the design process simply took advantage of the normal work day in different parts of the globe to speed the design activity. The process of making available the current applications, application results, and state of the design on a continuous basis throughout the globe would pose a significant burden on any networking environment envisioned.

7.1.3.2 Virtual Facilities

- Information Power Grid
- Wind Tunnels and Simulators

Information Power Grid

In addition to the specific application areas listed above, three types of virtual facilities were identified as demanding increasing telecommunications capabilities in the future. The first is the Information Power Grid which would provide heterogeneous distributed computing to users with both automatic and manual scheduling of computational and networking resources according to parameters set by the user and application. This information utility concept is being pursued nationally by NASA, NSF and NPACI (National Partnerships for an Advanced Computational Infrastructure) as a practical means of bringing together the information and computational resources to do truly interesting state-of-the-art application work in the future.

Wind Tunnels and Simulators

The other two virtual facilities that were identified were the wind tunnels and simulators. The designs and telecommunications required to make these facilities virtually available to the U.S. aerospace industry was seen as a necessary step in meeting visionary goals set for the aerospace industry. The goal was to make physical travel to these facilities unnecessary and also to quickly move the data generated by the experiments to the appropriate site for analysis.

7.1.3.3 Physics-based Deep Analysis

- Full Aircraft Aeroelastics
- Distributed Aircraft Optimizations

Another group of applications identified were termed physics-based deep analysis. These were differentiated from the above group of design applications by their increased need for basic understanding in the underlying sciences. The full aircraft aeroelastics and distributed aircraft optimizations are two of the applications identified in this category. By their nature, these applications generally require that distributed computational resources and disperse interdisciplinary science communities are brought together to solve the underlying problems.

7.1.4 Functional Network Capabilities

The networking capabilities identified were emerging trends or desires that did not focus directly on aerospace industry applications, but were felt to be absolutely necessary if the aerospace industry was to meet a number of its visionary goals such as increased safety, all weather flight, significant reductions in design cycle time, etc. The terms that arose during the discussion are revealing of the types of items in this category—peoplely things, telesocialization, resources, and data.

7.1.4.1 Human Factors—"Peoplely Stuff"

Networking capabilities refers to that broad category of services that extend beyond simple connectivity, and include sophisticated visualization, conferencing, resource and data management structures that can be operated in a distributed manner. This group placed significant emphasis on easing the researcher's ability to communicate with remote team members. It was felt that the widespread distributed collaboration that would be required in the future would demand better communication tools for the researchers as a starting point. The group identified significantly improved teleconferencing capabilities in the following forms:

- Offices—talking head visualization, whiteboards, sharing of screen data, etc.
- Meeting rooms—holographic conferencing, with 3-D representation of designs and people; discipline translator
- Classroom—lecture hall capabilities with interaction with lecturer and amongst participants
- Telesocialization room—distributed informal meeting places (coffee rooms, labs) with office-like conferencing capabilities

In addition, the group identified a discipline translator as a meeting room capability to assist the various groups in deciphering the jargon of the various attendees. What was envisioned was an acronym/jargon translator to assist the interaction of the multidisciplinary teams.

7.1.4.2 Computational Resource Structure

Besides the people-oriented things, considerable emphasis was placed on the use of the computational resource structure and the analysis and creation of data. A strong desire exists for the computation resources to be hidden from the users at whatever level of abstraction they desire. The group felt that, depending upon the application, a user could desire complete abstraction of the computational, network and data storage systems, or specifically manage the exact resources of the computation. In addition to scheduling and managing the computation, network and data, a history of the resources used must be kept. The scope of the Information Power Grid (IPG) effort at NASA is very much in keeping with the expressed feelings of this group. (The "Universal Job Queue" would have icons to drop jobs on; jobs would be dispersed and monitored; data transfers would be automated.)

7.1.4.3 Data Analysis and Creation

Information Visualization Environments

The third network capability that was discussed was the discovery and synthesis of data. Distributed visualization tools coupled with data extraction agents will be required. The group placed significant emphasis on the ability to customize and tune the data searches while always being able to reproduce the search for accuracy and data tagging. It was envisioned that the breadth of the searches could be very dispersed, if desired.

Analysis Environments

Another aspect that arose in this category was the design or engineering agent acting to keep a platform or environment current regardless of the number of participants involved. This was then extended to the concept of an analysis environment that would provide a desktop platform from which meta-computing services could be accessed, including all the services necessary to maintain versions and the current state of the analysis. Dynamic CORBA-like design simulators were also identified as network capabilities. These would be capable of combining simulations from anywhere and updating in near real time.

The direct effect on any future network design parameters from this and the prior section are not known—though more bandwidth and a wider reach are obvious goals. The next section deals with specific lower-level network descriptors that were identified throughout the group discussions.

7.1.5 Network Priorities

Specific networking descriptors were identified throughout the process that seemed essential to a future robust network infrastructure. Many of these are already on numerous lists of future capabilities from any well-thought-out network evolution. The group chose to rank the ones that surfaced to provide some guidance to how the networking efforts should be prioritized.

The network must provide a number of basic or elemental capabilities to begin the process of satisfying the higher level capabilities described above. This affinity group identified the following capabilities in a somewhat prioritized order. We do not believe they are unique to this affinity group and, from our perspective, are requirements that are completely expected by the networking community.

- “Prioritized” network capabilities
    - ◊ Guaranteed performance and predictability
    - ◊ Guaranteed security
    - ◊ Standard network services and management
    - ◊ Heterogeneity
    - ◊ Multicast and push technologies
- Unprioritized network capabilities
    - ◊ Billing mechanism for network services
    - ◊ Scalability
    - ◊ Standard peripheral interfaces
    - ◊ Process antibodies (protection systems built into the network)
    - ◊ Extended reach and connectivity.

In addition, network-based capabilities such as virtual file cabinets and storage were desired. These would be intelligent services with weeding, backup and archival mechanisms integrated into the service. Definable user interfaces were also identified as:

- Standard—what you expect on a daily basis in your office
- Nomadic—both wireless and nomadic in the sense that you could duplicate your office environment at another workstation regardless of connectivity type, and
- Collaborative—repeating a number of the office and meeting room requirements mentioned above.

Finally, the group also cited a need for massively parallel inefficient peering of resources and file system transfer protocols. The inefficient peering idea is the concept of having a standard means of distributing the work on cooperating idle resources (desktop computers in the night hours) without the complex optimization systems built into the IPG mentioned above. No one suggested that this would be used to run state-of-the-art applications, but simply to reduce the clock time for embarrassingly parallel desktop applications. The file system transfer protocol was seen as an extension of today’s FTP with the capability of file system transfers.

7.1.6 Conclusion

The Advanced Aerospace Design Affinity Group identified several aerospace applications that will clearly be enabled by new networking technologies. In general, the group did not identify any aspects of networking technology and related services that seemed totally unique or unexpected, but the emphasis on the human aspects of collaborative work was a bit surprising to everyone in the group. Some felt it was the makeup of the group, and others simply believed real progress in collaborative efforts could not be made without the human collaborative tools, regardless of the computational and networking infrastructure that was in place to serve the applications. The group agreed that the social side of aerospace design is critical and deserves more attention.

Appendix A: AAD Affinity Group Members

William Van Dalsem, Chair, NASA Ames
Christiy Budenbender, I-Net, NASA Ames
Neil Chaderjian, NASA Ames
Mike DeFrenza, Sterling Software, NASA Ames
Tom Dyson, Sterling Software, NASA Ames
Alyson Eby, NASA Ames
Marjory Johnson, RIACS, NASA Ames
Isaac Lopez, NASA Lewis
Anthony Quartuccio, Sterling Software, NASA Ames
Calvin Ramos, NASA Lewis
Todd Thompson, Lockheed Martin, NASA Johnson
Val Watson, NASA Ames

Appendix B: Slides

The slides below were presented by William Van Dalsem at the Plenary Session following the Affinity Group Discussions. Affinity Group members were asked to select five areas they considered the “most important.” These numbers, shown below in parentheses, were tallied to give a loose indication of the group’s ranking.

<u>Slide 1:</u>

HPCC/NREN Workshop

Advanced Aerospace Design, AAD Affinity Group
William Van Dalsem, *Chair*
Alyson Eby
Mike DeFrenza
Tony Quartuccio
Val Watson
Christiy Budenbender
Isaac Lopez
Calvin Ramos
Marjory Johnson
Tom Dyson
Neil Chaderjian

Todd Thompson

Slide 2:

Outline

- Applications
  Specific aerospace applications
- Capabilities
  Generic functional capabilities
- Descriptors
  Adjectives describing “network”
- Thoughts

Slide 3:

Applications

- Design Environments
  - AST High Lift
  - Helicopter Design
  - Advanced Shuttle Design
  - Engine Design
  - General Aviation
  - 24-hour Multi-partner design
- Virtual Facilities
  - Power Grid
  - Wind Tunnels
  - Simulators
- Physics-based Deep Analysis
  - Full Aircraft Aeroelastics
  - Distributed Aircraft Optimization

Slide 4:

Capabilities: Broad categories

• Peoplely Stuff	15
• Resources	4
• Data	21

Slide 5:

Peoplely Stuff (15)

- Office 5
  - Talking Heads
  - Whiteboards
- Meeting Room 8
  - Holo Conferencing

        - 3D “Holo” people
        - 3D “Holo” design
        - Discipline translator
- Classroom 1
    - 1:1
    - Lecture Hall
- Tele-Socialization 1
    - Coffee Room
    - Work Space/Lab

<u>Slide 6:</u>

Resources (5)

- Virtual Resource Access
    - Information Power Grid
        - Universal Job Queue
            - Icon, drop jobs on it,
            - Jobs are dispersed and monitored
            - Automated data transfers

<u>Slide 7:</u>

Data (21): Analysis and Creation:

- Information Visualization Environments 7
    - Data/Feature extractor 6
        - auto-tagging
        - tunable/customizable
        - accuracy
        - search large dispersed data
        - “English” query system
    - Design Update Agent 2
    - Engineering Assistant Agent 1
- Analysis Environments
    - Desktop aircraft analysis via meta-computing
    - Dynamic “CORBA” design simulation builder
        - Objects from anywhere
        - Push updating

<u>Slide 8:</u>

Elemental/Enabling Capabilities (5)

- “Push”/multicasting 3
- Virtual filing cabinets 1
- Spare cycle/bits protocol 1
- User Interfaces:
    - Common

  - Nomadic
  - Collaborative
- Virtual Storage, weeding and backup
- Massively intelligent inefficient peering
- File system transfer protocol

Slide 9:

Descriptors (9)

- Guaranteed Performance /Predictability 5
- Guaranteed Security 2
- Standard Network Services/Management 1
- Heterogeneity 1
- Charging $$
- Scalability
- Standard Peripheral Interfaces
- Process Antibodies
- Reach/Connectivity

Slide 10:
Thoughts

- Social side of design is:
  - Critical
  - Deserves more attention
- Rankings
  - May have been influenced by group make-up
  - Need to develop a refined nomenclature
  - More time needed
- Clearer requirements needed for such a diverse group - “application”
- Supply better coffee to dungeon teams

7.2 Astrobiology Affinity Group White Paper

7.2.1 Summary

The Astrobiology Affinity Group started out with a self-introduction by the participants in the NREN Applications Workshop II Astrobiology Affinity Group. This background information included a statement of affiliation and current and/or expected usage of NREN. A professional facilitator established ground rules for a productive collaboration, reviewed the goals of the meeting, and asked thought-provoking questions like, “What problems does the science of astrobiology face in the next five years?” The group produced an extensive list of issues, a complete listing of which is found in the “Challenges/Problems” section.

The next step was to group the stated issues and problems into four key areas: programmatics, science, network and computing, and education and outreach. While it was clear which focus several of the problems mapped to, others spanned two or more of the main categories. A complete mapping, as defined by the group, is found in the “Challenges/Problems” section. These exercises were designed to surface specific applications that would address the carefully grouped problem areas.

The applications were then grouped into network classifications, as defined by the NREN team at Ames Research Center:

> Class 1 is networking research in a potentially unstable environment.
>
> Class 2 comprises research networks with more reliability than Class 1, but less than would be considered usable by most users.
>
> Class 3 covers operational networks that use “state-of-the-art-technology,” often attainable as commercial, off-the-shelf applications and hardware, and
>
> Class 4 covers production networks, what we currently think of as the Internet and/or other similar intranetwork technologies.

Each participant was assigned as a proponent of at least one application that was generated. Although many ideas were developed, the group identified three specific target application areas: Telepresent Robotics, Remote Instrument Operation and Telecollaboration, and Distributed Processing and Modeling.

The Astrobiology Affinity Group deliberations culminated in a presentation to the plenary session by the group’s Chair.

7.2.2 Introduction

The following is background information on the field of astrobiology obtained from the NASA Ames Research Center’s World Wide Web page. While not all-inclusive, it describes some of the topics that the field of astrobiology faces in the future. More specifically, it explains the importance of astrobiology in the context of NASA Missions.

7.2.2.1 NASA's Astrobiology Program

Astrobiology is the scientific study of the origin, distribution, and future of life in the universe. NASA’s initiative in astrobiology is a broad science effort embracing basic research, technology development, and flight missions. It is conducted at several NASA Centers and in the academic and industrial communities, with a lead role for management of the proposed Astrobiology Institute assigned to NASA's Ames Research Center in Mountain View, California. This initiative involves:

- *Basic research*, carried out by scientists in universities and other laboratories across the nation. These research programs are supported in response to peer reviewed proposals to carry out specific interdisciplinary studies.

- *Missions to space*. These include biological aspects of the study of stellar nurseries in which planets form and organic molecules are synthesized, search for life on Mars, identification of habitable planets circling distant stars, and experimental studies of the adaptation and evolution of life in space.
- *Astrobiology Institute*. The Institute, managed by Ames Research Center, is a national consortium of scientists focused on interdisciplinary research, while also training a new generation of researchers with the broad skills, intellect and enthusiasm to realize the future potential of astrobiology.
- *World Wide Web*: Astrobiology will take advantage of the World Wide Web and other information systems to share the excitement of exploration with the public. As with all NASA programs, there will be a strong educational component—because we wouldn't dream of exploring the living universe without taking the kids along!

7.2.2.2 Astrobiology Research Opportunities

- How did life begin? Modern science is able to approach this question from many directions. How did life originate on Earth? What are the processes of self-organization that led to the formation of membranes and cells? How did the first living systems acquire the ability to metabolize and reproduce? Within 15 years, we expect to have the answers to many of these questions.
- To understand life's beginnings, we need to place it in its cosmic context. Are there other habitable worlds besides the Earth, either in our solar system or far beyond it? What is the origin of the water and organic chemicals that are the raw materials for life? Several NASA missions, such as the Space Infrared Telescope Facility, the Stratospheric Observatory for Infrared Astronomy, and the Next Generation Space Telescope will answer many of these questions.
- We seek to understand our place in the universe, and to answer the age-old question, "Are we alone?" If we find Earth-size planets circling distant stars, can we determine their potential for life? What features are key for recognizing habitable planetary systems? Within 15 years we should be able to study individual Earth-like planets if they exist around nearby stars.
- The Earth was a very different place 3.8 billion years ago, the age of the oldest fossils. How has the Earth and its biosphere evolved and interacted? And what are the implications of the environmental changes happening today? Comprehensive monitoring of our planet by the Earth Observing System in combination with ongoing academic research efforts will provide many answers.
- Is there life on Mars or in the ocean of Jupiter's moon Europa? Where on these bodies should we search for life and its fossils, and how can we recognize them? Will all life be much like us, or will it differ in exciting ways? The study of life in extreme Earth environments and retrieval of Martian

samples should answer some questions within 10 years, while others may require human flights to Mars.

- The first outposts of life are now in orbit, and within the next generation we may move outward to the planets. How will terrestrial life adapt and evolve in extraterrestrial environments? Can we study evolution experimentally in space or on other planets? Research on the Space Station will address these basic questions within the next decade.
- How can we understand how physical factors such as gravity and radiation influenced our genetic history? What are the prospects for establishing stable ecosystems on Mars that can support long-term human presence on that planet? These questions are addressed by a combination of laboratory studies, experiments on the Space Station, and the unfolding of the NASA Integrated Mars Exploration Program.

7.2.2.3 Current Findings of Interest to Astrobiology at NASA

The level of interest and excitement in these areas may best be demonstrated by listing recent discoveries that have set the stage for NASA's astrobiology initiative:

- We have analyzed complex organic chemistry in interstellar clouds of gas and dust and have discovered planets circling other stars.
- On Earth, life has been found thriving in Antarctic rocks, in boiling hot springs, at the ocean depths, and deep underground.
- We know that liquid water, the essential ingredient for life as we know it, once flowed on the surface of Mars and probably exists today below the icy crust of Jupiter's moon Europa.
- A rock from the ancient Martian crust has revealed tantalizing hints of fossil microorganisms that may have lived more than 3 billion years ago.
- Life on Earth has been traced back 3.8 billion years to the period when heavy cometary bombardment brought life-giving water and organic chemicals while battering Earth with lethal quantities of impact energy.
- We are discovering both the fragility and robustness of life as we investigate the history of mass extinctions on our planet, subtle alterations in climate triggered by atmospheric changes, and the partial destruction of our protective shield of ozone.
- While we celebrate the ability of astronauts to live and achieve wonderful feats of engineering in space, we ponder the implications of baffling physiological and chemical changes induced by the space environment. We are only beginning to probe the adaptability of life to conditions beyond our home planet Earth.

7.2.3 Challenges/Problems

Below is an extensive list of issues and problems facing the astrobiology community, followed by groupings of these issues into four key areas: programmatics, science, network and computing, and education and outreach. Several of the problems spanned two or more of the main categories. These exercises were designed to surface specific applications that would address the carefully grouped problem areas.

7.2.3.1 Aspects of Astrobiology Problem Areas

- Interdisciplinary
- What is astrobiology
- Multi-interdisciplinary
- Paradigm nudging
- Scale: broad, temporal and spatial
- Science vs. hardware
- Laboratory field and theoretical studies
- Programmatic ownership
- Funding
- Relation to overall Agency mission
- Education outreach vs. research
- Define players
- Directing of research
- Programmatic styles
- Metrics (how do you evaluate)
- Strategic planning
- Missions (Mars, Europa, Titan)
- Virtual lab
- Social and political feedback/modulation
- Self-organization
- Extreme environments
- Biospherics
- Terraforming
- Information theory
- Artificial intelligence
- Extra-solar planets
- Planetary impacts and global ecology
- Cyborg
- Human expansion
- Carbon chauvinism
- Understanding consciousness
- Planetary formation and evolution

- Evolutionary biology
- Origin & distribution of biogenic elements
- Instrument design
- Panspermia
- Training the next generation of astrobiology
- Analysis of metadata
- Faster than light (FTL) travel
- Proof positive of extraterrestrial life
- Proof positive of extraterrestrial intelligence
- Physical/chemical factors in life
- Polar deserts
- Terrestrial analogs to extraterrestrial environment
- Planetary protection (quarantine)
- Digital thought communication
- Human/computer interface
- Comparative planetology
- Encryption algorithm
- Data collection, transfer, storage and use

7.2.3.2 Aspects of Astrobiology Problem Area Mappings
Programmatic:

- Programmatic ownership
- Direction of research
- Define astrobiology (vs. ExoB)
- Programmatic styles
- Strategic planning
- Interdisciplinary
- Multi-interdisciplinary
- Define outcome
- Funding
- Relation to overall agency missions
- Social and political feedback/modulation
- Science vs. hardware
- Define players
- Metrics
- Lab, field and theoretical studies
- Human chauvinism
- Planetary protection
- Ethics
- Human expansion beyond Earth

    - Education outreach vs. research
    - Virtual labs
- *Science:*
    - Proof of extraterrestrial life
    - Extra solar planets
    - Proof positive of extraterrestrial intelligence
    - Scale: broad, temporal and spatial
    - Terrestrial analogs to extraterrestrial environment
    - Comparative planetology
    - Mars, Europa, Titan missions
    - Ecology
    - Physical/chemical factors in life
    - Origin and distribution of biogenic elements
    - Biospherics
    - Self-organization
    - Evolution
    - Planetary evolution and formation
    - Planetary impacts and global ecology
    - Lab, field and theoretical studies
    - Understanding consciousness
    - Panspermia
    - Extreme environments
    - Evolutionary biology
    - Evolutionary
    - Human expansion beyond Earth
    - Virtual labs
    - Telepresence

Networks and Computing:

- Information theory
- Archival storage
- Cyborg
- Encryption algorithm
- Analysis of metadata
- Data collection, transfer, storage and use
- Human computer interface
- Artificial intelligence
- Digital thought communication
- Virtual labs
- Telepresence

Education and Outreach:

- Training the next generation of astrobiology
- Education outreach vs. research
- Interdisciplinary
- Multi-interdisciplinary
- Paradigm nudging
- Courseware development
- Teacher training
- Information dissemination
- Multimedia resource availability
- Collaboration independent of location
- Teacher, scientist partnership
- Data collection, transfer, storage and use

7.2.4 Astrobiology Applications

The group was able to identify many possible applications for future consideration. Among these are following:

- *Europa—ROV: in situ life identification of characterization environment*

  Subsequent to the findings of the Galileo mission to Jupiter, future missions to the jovian system are likely to focus intensive scrutiny on Europa. This moon has a young (<10 million years old) ice-covered surface, and extensive evidence of fracturing processes and resurfacing that appears compatible with the presence of a liquid water ocean beneath a thick layer of ice. Eventually, missions to Europa may be able to penetrate the icy surface and investigate the ocean below, using robotic technology very similar to that which has opened up the ocean depths on Earth. Techniques to enable remote linkage to robots on Europa that would enable scientists on Earth to interact with the subsurface environment as if they were there (i.e., telepresence) will greatly enhance science return from such missions and further our understanding of this potential life site.

- *Mars—bimarker telecharacterization*
- *Astronaut headward fluid shift imager*
- *SETI Telescope on Moon (farside)*
- *Board, software, and generic instrument and interface standard for personal computers*
- *Real-time implantable sensor remote monitoring system*
- *High throughput—remote access of state-of-the-art instruments (e.g., electron microscope)*
- *Much improved teleconferencing*

- *Real-time collaborative, distributed computation and modeling of planetary climates:*

    If it were possible for modelers to be in real-time communication with each other, via videoconferencing, for example, and if it were possible for modelers to be able to distribute their model processing loads across a network of supercomputers, the process of modeling such phenomena as changes in the physical and chemical nature of planetary atmospheres could be facilitated.

- *Telecommand of remote supercomputer in situ data collection system (selectable telepresence)*

For the remote exploration of a planetary surface or the subsurface realm, a combination of autonomous robotic capability and telepresence linkages would enable heightened science return, and allow more robust exploration capabilities. An autonomous vehicle or platform that could independently deal with the challenges of simple locomotion and navigation could be greatly enhanced if it were able to be operated in a telepresent mode upon arrival in a choice location, or upon the discovery of something truly unusual.

- *Distributed real-time display and processing (e.g., of SETI)*

7.2.5 Priority Application Areas

The Astrobiology Affinity Group identified three priority application areas:

1. Telepresent robotics
2. Remote instrument operation and telecollaboration
3. Distributed processing and modeling

7.2.5.1 Telepresent Robotics

- ROV (Remotely Operated Underwater Vehicle)
- Surface rover
- Telepresence for multiple users at remote sites
- Supported by virtual reality tools a la Pathfinder (polar underwater, and meteorite searches --> Mars, Europa, Titan)

Space scientists are interested in developing new technologies and opportunities to enhance the use of robotic vehicles for real-time science and exploration. These uses typically can require large bandwidth capabilities and uninterruptable communications and network access between the controller of the robot and the target area for exploration. Because of the essential difficulties of visiting waters of greater than a few tens of meters in depth, the ocean sciences community also has a great deal of experience with, and a firm requirement for the use of remotely operated underwater vehicles.

Technology developed by NASA for space science usage can be employed now in the study of the oceans, and has the potential to greatly assist scientists who are unable to enter the appropriate environment on their own, but use artificial means to access sites of interest. The use of telepresence technology in the marine environment can revolutionize the use of remotely operated vehicles, and particularly may enable some researchers to make use of sites of opportunity on ships that may be carrying such vehicles, but whose ability to make all of its commitments may be limited. In such a case, an investigator may be able to make use of a ship-of-opportunity without ever leaving the comfort of the home institution. Currently, NASA is working with the U.S. Coast Guard and NOAA's West Coast and Polar Regions Undersea Research Center to implement telepresence capability in support of science activities in the Arctic and Antarctic, using NASA-owned ROVs to support both NOAA- and NSF-supported science projects.

7.2.5.2 Remote Instrument Operation and Telecollaboration

- High data throughput/high cost scientific instruments (short-term)
    - ◊ Telecollaboration for materials microcharacterization (e.g., electron microscopy for Mars meteorite studies)
    - ◊ Remote operation of telescopes (SETI)
- Generic tools and standards to allow collaborative telecontrol of instruments on an *ad hoc* basis - “plug and play” (long-term)
    - ◊ FTIR, optical microscopes, NMR, PET, X-ray, etc.

7.2.5.3 Distributed Processing and Modeling

Computer-based modeling is an extremely time- and computer-resource-intensive activity. Individual runs can take many cycles of CPU time on even the fastest supercomputers. Further, results of intermediate runs must be analyzed, leading to changes in initializing parameters prior to another run. Often, discussions among colleagues can take a long time, only after which can computer time be scheduled.

Real-time collaboration, based on real-time runs of complex, computer-based models using spare cycles of CPUs of supercomputers connected by fast networks would support broader and more in-depth development and calculation of models, and their analysis, as well.

A few of the astrobiology discipline areas that could benefit from this real-time collaboration and modeling include (but certainly are not limited to):

- Planetary environments
- Ecosystem dynamics
- Self-replicating systems
- Neurovestibular array structure and function (biocomputation)

- Instrument design
- Origins of solar systems
- Data mining

7.2.5.4 Other Issues

In the course of the group's deliberations, some concerns that crossed all current and future application areas arose. These fell into two major areas that the group felt strongly must be addressed by NREN to ensure the success of NREN initiatives and activities:

- Core tenets of all applications
  - ◊ Much improved teleconferencing
  - ◊ Instrument and network/session integrity
- Specific network issues
  - ◊ Network reliability for instrumentation command and control
  - ◊ Security of proprietary and pre-decisional data
  - ◊ Effective and responsive bandwidth for remote human collaboration
  - ◊ Ability to incorporate multiple data and media types independent of platform

7.2.6 Conclusion

Focus on the Internet is critical to astrobiology, but it will rely not only on the use of the forward looking Next Generation Internet, but also on "backward compatibility" so that existing capabilities are not overlooked.

The participants in the Astrobiology Affinity Group were pleased with the results of the workshop. It is clear that there are definite opportunities for NREN to partner with and to support astrobiology applications. An added benefit of the interactions within the group is that the group now has contact information for further communication on established and future applications.

Astrobiology Affinity Group Members

Dr. Robert A. Wharton, Jr. - Discipline Chair, Desert Research Institute
Linda Boyd - Facilitator, PowerPoint Associates
Kevin L. Jones - Network Expert, NASA-Ames Research Center
Doris Chow - Administrative, NASA-Ames Research Center
John D. Rummel, Ph.D., Marine Biological Laboratory
Michael Kolitsky, Ph.D., University of Texas at El Paso
Mitchell K. Hobish, Ph.D., Consulting Synthesist
Lee Henrikson, SETI Institute
Lawrence F. Allard, Ph.D., Lockheed Martin, Oak Ridge National Laboratory

Keith L. Cowing, American Institute of Biological Sciences
Dr. David P. Summers, NASA Ames Research Center
David F. Blake, Ph.D., NASA Ames Research Center
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7.3 Astrophysics Affinity Group White Paper

7.3.1 Summary

The Astrophysics Affinity Group held its first meeting on September 17, 1997, at the second NASA Research and Education Network (NREN) workshop held at Ames Research Center. The group's main focus was to determine key problems and research-oriented tasks which NREN could provide support for in the coming years.

The Astrophysics Affinity Group started out with a detailed explanation of what astrophysics constitutes and its relationship to astrobiology. This was deemed essential as the affinity group had more engineers than astrophysicists and there was a general need to understand the area of astrophysics.

The group then identified the challenges in astrophysics and possible application areas in which NREN may be helpful in providing solutions.

7.3.2 Introduction

7.3.2.1 What is Astrophysics?

Astrophysics addresses a fundamental question of the origin of the universe—how the universe began, what the universe will be millions of years from now, and its ultimate fate. Astrophysics also addresses the questions of the beginnings of the galaxies, stars and planetary systems—how these formed millions of years ago and their evolution. Physical processes in extreme environments (e.g., black holes) are other fundamental areas in which astrophysics attempts to provide answers.

7.3.2.2 Importance of Astrophysics to NASA

Many of the fundamental and outstanding science questions of the day regarding the origins, structure, and evolution of universe, the Sun-Earth connection, and solar system exploration can only be addressed by going into space. As the agency charged with such space exploration activities, astrophysics plays a very important role in NASA's charter.

Astrophysics in NASA takes many forms and shapes—both airborne and ground-based observatories aid in the study of astrophysics. These capabilities are poised to answer fundamental questions about the formation and evolution of the universe and life.

7.3.2.3 Astrophysics and Computer Networking

The study of astrophysics, which involves astrophysicists and observatories in every corner of the Earth, has direct and indirect links to computer networking and every aspect of computer communications. Simply put, the heart of astrophysics is “photons and their collection.” NASA’s mission in the area of astrophysics is:

> “. . . to use knowledge and discoveries about the Sun, the solar system, the galaxy, and the universe to promote education and public outreach opportunities and activities to enhance science, math and technical education.”

The underlying theme is the collection, combination, and distribution of such astronomical data to understand how astronomical processes work. This clearly indicates the powerful relationship between “research networking and astrophysics.”

7.3.3 Challenges and Key Applications

The challenges in astrophysics identified by the Astrophysics Affinity Group deal with collection and dissemination of astronomical data as applied to networking. These challenges include:

- Data dynamics
- Collaborative computing
- Collaborative human interaction
- Coordinated, multispectral, multisite observation
- Telepresence

The following discussion considers problems and possible application areas in which NREN may be helpful in providing solutions.

7.3.3.1 Data Dynamics

The term “data dynamics” was coined to represent the myriad ways and amount of data being handled routinely. Data dynamics can be classified in two main focus areas which are elaborated below: observation and collection of data; and analysis and understanding of the data collected.

Observation and collection of data:

Data dynamics depend on observing platforms located on the ground, in the air, and in space for observation and data collection. Ground-based telescopes in far-off places (on mountain tops and in flatlands, most of them robotically controlled) point to the sky and collect data; space-based observatories (e.g., Hubble Telescope) routinely beam down data collected from the universe; and airborne platforms (e.g., SOFIA) conduct studies on a regular basis. All of these provide “a mountain of data” to be distributed and understood.

Advanced networking technologies can enable efforts to distribute data to different corners of the world by using capabilities such as asynchronous transfer mode and next generation networking technologies to provide a network infrastructure that can offer different levels of network services to users at costs based on the characteristics of the services.

Command and Control:

Command and control refers to remote control of telescopes and other equipment, whether terrestrial or space-based. An advanced network such as NREN is needed to assist development of remote real-time data acquisition, remote instrument control, and development of fail-back systems that operate upon loss of such a networked command and control system.

Data Distribution: Archival, Analysis, and Understanding:

To a large extent data distribution is not a real-time effort. However, that is rapidly changing as computational modeling and sophisticated real-time collaborative tools are coming into wider use. Development of new algorithms and new ways of analyzing data now allows archived data to be re-analyzed, with some startling results in the field of astrophysics. There are now constant demands to retrieve data stored remotely both in real time and non-real time. A high speed network such as NREN can go a long way on fostering increased collaboration among researchers.

Once data are made available, sophisticated computer and analytical modeling (usually in three-dimensional space) bring out newer results which lead to newer ways of looking at and exchanging information with researchers worldwide. Such an understanding leads to increased collaborative efforts and newer discoveries (e.g., the discovery of comet Hale Bopp).

Dissemination (education and outreach):

One of the areas important to NASA is to educate the public about the efforts in astrophysics research being conducted and the results achieved.

7.3.3.2 Collaborative Computing

Astrophysicists often need to collaborate with their colleagues to exchange data and analyze results. Data exchanged for computer modeling and simulation often run into millions of bytes which require computer resources to be made available in real time. Any intermediate changes require the use of the very same resources continuously.

Such real-time collaboration, based on resources being made available in real time to enable leading-edge research, require use of networks which have to scale in both speed and bandwidth to provide such connectivity. The astrophysics research community must determine how NREN could help identify solutions to astrophysics challenges.

7.3.3.3 Collaborative Human Interaction

One of the more common applications that this group focused on was the availability of networked videoconferencing facilities. Such availability would greatly enhance collaboration among researchers. Further, in these times of budgetary cutbacks, videoconferencing would be a great help in eliminating travel to meet other researchers.

7.3.3.4 Coordinated, Multispectral, Multisite Observation

Observation of the sky is not an isolated event but involves researchers, space enthusiasts and other interested parties. Such efforts have led to many discoveries in the recent past. The astrophysics community has developed ways to keep all of these elements informed of the latest developments (e.g., when an observation leads to new results), but it still does not use the latest developments in technology for such an effort. While the demand on bandwidth is minimal for coordinated observations, the speed with which the coordination takes place is nevertheless critical.

In the future, coordinated observations will require a reliable network interconnecting the world's observatories and research institutions. When an unusual astrophysical event is detected at one observatory, notification of the event will be automatically transmitted, *in a matter of minutes,* to all other observatories on the network allowing them to take appropriate steps to observe the event in a coordinated fashion. Furthermore, communication (possibly high bandwidth) between sites may be required during the entire lifetime of the event to support ongoing, coordinated observation. Such coordination could be accomplished by a highly advanced network connecting institutions and groups/researchers.

7.3.3.5 Telepresence

Remote exploration will require mobility. Efficient and low-cost operation of mobile robots will be a key requirement for future exploration of the universe. Telepresent control of mobile robots may well prove to be an enabling technology for answering the most compelling scientific questions about our nearest planets. It will also be critical for scientific operations during future human missions.

Simulations and analysis (e.g., for remote monitoring of telescopes) will be critical for science operations on future human missions. Experiments show that mobile robots can be used to successfully perform field geology on other planets. Thus, next generation computing networks will be seen as one of the main enabling technologies.

7.3.4 Conclusion

The participants in the Astrophysics Affinity Group were pleased with the results of the workshop, given that this was the smallest of all the affinity groups. Further, within the small group there were more network engineers than core astrophysicists.

NREN has an opportunity to partner with the astrophysics community to further research in this area by providing cutting-edge networking support. Many of the areas in which astrophysics can utilize next generation networking technologies in the next several years are clearly known. The question is how to best apply these networking advances to meet information technology challenges. There will be additional interaction between NREN and the astrophysics community to assist in determining how NREN can best help identify solutions to astrophysics challenges which in turn would advance NASA’s efforts.

Participants

Bruce Smith, Ames Research Center, Discipline Chair
Williard Smith, Tennessee State University
James Harrington, Goddard Space Flight Center
Vishy Narayan, Ames Research Center
Eric Bobinsky, Lewis Research Center
R. Sardy,

Larry Chao, Ames Research Center
Sean Casey, Ames Research Center

7.4 <u>Earth Sciences</u> Affinity Group White Paper

7.4.1 Introduction

The Earth Sciences Affinity Group (ESAG) of the NREN Workshop met September 17-18, 1997, at Ames Research Center. The ESAG was chaired by John Steedman, NASA Earth Science Data and Information System (ESDIS) Networks, Kirk Bridgeman, who was the group facilitator, Dora Lopez and Grant Miller, Network Advisors, and Pat Kaspar who served as administrative support. An attendee list is provided at the end of this document.

Since the majority of the attendees were network experts rather than Earth science researchers, it was suggested that:

- Discussion focus on Earth science applications, rather than specific network research areas.
- Discussion should consider applications in the context of future tools that might be developed.
- Focus should be on applications that can only be demonstrated and/or facilitated by the advanced technologies of NREN.

As a result, the group focused on three key areas for discussion:

- Identifying applications requiring high performance capabilities over the next five years,
- Gathering data on these applications, and
- Prioritizing applications to support Earth science missions.

7.4.2 Identification of Applications over the Next Five Years

The Earth science community has been developing applications and tools which require broadband and increasingly sophisticated networking capabilities. For example, Earth scientists have been developing visualization applications which summarize and display increasingly large data sets and which require increased bandwidths to support the calculations of the visualization products. They often require significant bandwidths for user retrieval if they are to be viewed at a remote site.

The Distributed Image Spreadsheet developed by Dr. Palaniappan and Fritz Hasler is one example of the growing demands placed on networks by visualization models. This application uses large amounts of bandwidth to retrieve multiple data sets from distributed, remote data and information centers. It provides near-real-time assembly of the data into visualization products and display of these products. If greater bandwidth with increased throughput of data sets is provided, the visualization tool can be continually refined and improved.

The Earth Observing System (EOS) Program increasingly requires broadband network services capable of supporting Quality of Service (QoS) requirements (latency, delay, security, and low error rates) for Quality Assurance of data products as they are produced, and for Instrument Support Terminal communications to the EOS Data and Information System (EOSDIS) Operations Center. While these requirements may be met with dedicated network links, requirements could potentially be provided at significantly reduced costs using the capabilities of new technology networks such as NREN. Applications such as link reservation, priority of service and switched virtual circuits need to be prototyped and developed as reliable capabilities to implement these types of services.

7.4.2.1 Crosscutting Technologies

The applications and services cited by the scientists as being required over the next five years are supported by specific crosscutting network technologies under the NREN program. These crosscutting technologies include:

- Multicasting
- QoS, including network reservation, prioritization of traffic, and classes of service
- Security
- Multimedia
- Visualization
- Intelligent data discovery
- Collaboratories
- Administration and accounting algorithms

7.4.2.2 Earth Science Applications

The above crosscutting technologies support a wide range of Earth science applications. The potential applications may be characterized very generally as:

- Education initiatives
- Critical real-time applications (e.g., severe weather warnings, disaster mitigation/monitoring)
- Visualization applications (e.g., the Distributed Image Spreadsheet, telemedicine and other applications demonstrated at this conference)
- Support of EOS requirements [including instrument support terminal communications with the EOS Operations Center, Quality Assurance

Science Computation Facility (QA SCF) science data requirements, DAAC connectivity to the Internet to distribute data to users, and user access linkage to the DAACs to identify and order data]

- Connectivity to other advanced networking infrastructures (e.g., other NGI networks and Internet 2)
- Reliable multicast (e.g., the Globalcast/Lucent reliable multicast program at GSFC)
- Digital libraries
- International collaboration [e.g., SINET at 150 Mbps scheduled for March 1998 connectivity to the Ames Next Generation Internet Exchange, and German Research Network (DFN) connectivity to Perryman, NJ, at 2XDS3]

Each Earth science research program will be distinct and require differing elements of the Earth science applications listed above. The above applications are basic capabilities that will provide new opportunities and capabilities of the Earth science researchers within their own unique programs. They provide tools and capabilities that the researchers can use to quicken the pace of development of their science projects.

7.4.2.3 Scope of Applications

These technologies and applications would be particularly useful for researchers to implement new Earth science applications in the areas of:

- Further development of the Distributed Image Spreadsheet,
- Collaboratories for scientists,
- Mobile access, and
- Distributed time clock (e.g., for time stamping).

In general, the scope of applications that would be enabled by NREN is indicated below. Each of these potential categories may use NREN capabilities in a wide range of applications. A specific researcher will require a unique set of support for his specific research objectives.

- *Data collection*, satellite, aircraft, in-situ
- *Modeling*, including distributed heterogeneous model linking, mesoscale
- *Validation and field experiments*: measurement and model results
- *Archival*, including coordinating among archival data centers and developing and coordinating metadata such as browse images
- *Access and distribution:* access to metadata and data sets, and distribution of the metadata and data
- *Computational*, including remote access to computational resources and coordination of parallel processing on distributed heterogeneous computers

- *Use and application of data*, distribution of data and information to classes of consumers.

7.4.3 Gathering Data on Applications Requiring High Performance Capabilities

The ESAG scientists identified the following needs:

- *Remote access to data and information* stored at distributed, heterogeneous data sites. Scientists typically access the EOSDIS to identify and retrieve the data sets and subsets of interest to their particular work. These data are stored at their home site for easy access and use. To change this method of storing and accessing data, scientists are developing tools which will demand fast, reliable, and secure communications.
- *Increasingly sophisticated collaboration tools* including multimedia conferencing, whiteboarding, and the capability for distributed users to work on a common model.
- *Support for all applications represented in digital libraries*, such as data storage, catalog, directory and inventory services, intelligent search engines, and robotic search and retrieval technologies.
- *Provision for increasing international services over networks*, such as data location and retrieval from remote sites such as Japan and Europe.

The ESAG identified broad categories of potential Earth science researchers who would benefit from the increased capabilities of NREN and other research networks. These categories include:

- *Scientific*: researchers at universities and institutions, international researchers, commercial researchers, and others
- *Socioeconomic*: researchers who incorporate demographic and economic data to identify human impacts of Earth science, such as pollution areas associated with urban development or deforestation associated with economic development.
- *Policy*: environmental regulation officials who develop policies for mitigating environmental impacts.
- *Education/Public*: educational users include those who access Earth science data and resources in support of educational programs; public users include general users accessing Earth science data via the Internet such as users accessing Mars Pathfinder images over the Internet.
- *Libraries/Institutions*: Libraries and institutions access, store and distribute data, often generating additional metadata or derived data that they feel would be useful for their users. They serve as intermediaries in access of the data and often provide value-added data products.
- *Operational/Near-real-time*: this category includes weather forecasters, resource evaluators such as fisheries, and disaster prediction, monitoring,

and mitigation users. They often have specific requirements for timeliness, accuracy and security which NREN and other prototype networks may address through their research programs.

7.4.4 Prioritizing Tools and Applications

The Earth science participants summarized and prioritized the tools and applications required to support their developing programs and applications, including:

- *High performance access to remote archives*
  - Intelligent data discovery and autonomous robotic data discovery
  - Data systems cooperation, e.g., catalog interoperability
  - High speed
- *Collaboratories*
  - Support for nomadic users
  - NREN prototyping support for widely different performance levels (e.g., if the requirement is for 1 Mbps one day and 1 Kbps the next day, the network decides how to best make use of the 1 Kbps)
- *Distributed interdisciplinary modeling*
  - Large-scale distributed parallel computing
- *Visualization*
  - Advanced and distributed visualization tools with near-real-time capability, e.g. Distributed Image Spreadsheet
- *Simultaneous support of different classes of service*
  - Mission Critical, QoS, link reservation, expendable

These tools will be ubiquitously applied to the following application areas:

- Climate modeling (e.g., modeling long-term trends)
- Atmosphere/weather modeling (e.g., near-real-time weather forecasting)
- Disaster mitigation and response
- Resource assessment (e.g., fishing resource and forestry resource assessment)

The tools/applications and applications areas presented above may be represented in a two-dimensional matrix where the matrix cells represent the specific adaptations of the tools and applications required by the specific application area. A third dimension of this matrix is represented by the user types discussed above. The user-specific requirements will provide additional details on the developments required to support the users/applications.

7.4.5 Conclusions

The ESAG identified that the development of advanced applications is critical to support the improvement of Earth science research, modeling, and collaboration. Advanced applications over NREN can significantly improve the capabilities of the scientists to access metainformation, find the information they require, transfer large data files, perform distributed computing and modeling, work in collaboratories, and provide distributed access to the results of their work. Important applications requiring development to enable these capabilities include:

- Common protocols and formats for data sets and data transfers
- High speed access and delivery capabilities to remote facilities
- Mobile applications to support remote access and delivery of data
- Development of advanced, and distributed visualization tools to facilitate location of appropriate data sets
- Autonomous robots to discover, subset, and return appropriate data sets
- Seamless advanced networks to support collaboratories
    - Whiteboarding
    - Distributed computing
    - Teleconferencing
- Digital library development

7.4.6 Recommendations

The ESAG made several recommendations for future NREN conferences. In particular, they felt that increased representation by the scientists within the Earth science community would greatly benefit the ESAG. This could be provided by enlisting scientists at the EOS science panel meetings, providing NREN presentations at science discipline conferences, and providing a separate affinity group for networking experts. The ESAG also felt that the probabilities of being able to enlist the participation of additional scientists could be improved by concentrating their participation on one day of the conference, by providing them with extensive background materials in advance of the conference, and by continuing the current practice of defining focus topics for the affinity groups to coordinate and focus discussions.

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7.5 Space Exploration Affinity Group White Paper

7.5.1 Introduction

NREN Workshop II was held on September 15 - 17 at NASA Ames Research Center, Moffett Field, California. Several groups of scientists and network engineers met to discuss the types of future network applications needed by the NASA science community to help them in their daily work.

The focus of this White Paper is on the Space Exploration Affinity Group's activities at the NREN Workshop. Primarily, the group activities were concentrated on listing and prioritizing applications that are being considered within a three- to five-year time frame. The space exploration scientists who attended the Workshop were primarily planetary geologists from Ames. Therefore, the discussion was skewed towards their needs and did not represent other space exploration disciplines such as planetary imagery, atmospheric physics, astronomy chemistry, and space physics. These areas of interest will be explored in follow-on activities.

Surprisingly, the Space Exploration Affinity Group (SEAG) listed a critical and urgent need for easy access to digital libraries for review and downloading of scientific articles and journals in order to perform research in their fields. Currently, there is a joint venture initiative between NSF, DARPA and NASA to build a comprehensive storehouse of information through the Internet called the Digital Library Initiative.[1]

The second important item was the dire need for 3-D type analysis and collaborative tools that could be run over a wide area network (WAN). Currently most of the planetary geologists have to run mathematical equations and plot the probability curve of geological events over 2-D graphs manually. These 3-D tools will enable geologists to plot and view geological events in a holographic fashion.

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[1] $24.4 million is funded for the Digital Library Initiative for a four-year project between the three federal agencies. Efforts are being made to bring together researchers from academic institutions, libraries, museums, publishers, government laboratories, state agencies, secondary schools, and computer and communications companies to make available vast stores of knowledge and innovative information to researchers, students, educators and the general public. (www.cise.nsf.gov/iris)

The third need mentioned was the need for Planetary Expedition Networks (PENs) prior to sending manned space missions to any of the planets. PENs should include a virtual reality capability to handle rover activities, a Global Positioning System (GPS), a satellite-based navigation system on the planets, the existence of network science (e.g., for seismology measurements), and a high capacity network infrastructure for data/voice/video communications between intra- and interplanetary posts.

The primary focus of this White Paper is on the Space Exploration science community's needs for the high capacity network to support future NASA's missions. Space exploration is important to NASA's mission. NASA has listed as its primary missions (*www.hq.nasa.gov*):

- To advance and communicate scientific knowledge and understanding of the Earth, the solar system, and the universe, and the use of the environment of space for research.
- To explore, use, and enable the development of space for human enterprise.
- To research, develop, verify, and transfer advanced aeronautics, space, and related technologies.

Space is mentioned in all three primary objectives; in fact, the "S" in NASA stands for space.

The NASA space science program seeks to discover the frontier of space within the sphere of human activities in order to build a better future for mankind by discovering the mysteries of the universe, exploring the solar system and searching for life beyond Earth.

The program consists of a continuing series of missions to explore the inner planets and the near-Earth asteroids; a series of spacecraft missions to explore the outer planets, comets, and asteroids; development of a multimission spacecraft operations and data analysis capability; and ground-based research, analysis, and related activities.

7.5.2 Network Challenges

Three basic network challenges facing the space exploration group include:

1. High performance network for terrestrial communications to enable virtual reality-type collaborative and analysis tools over the Internet and access to digital libraries.
2. High performance network between planetary outposts and Earth.
3. High performance network between intraplanetary networks such as PEN and the GPS.

7.5.3 Applications Challenges

Twelve key applications challenges were identified by the group during the brainstorming session. These twelve items were then categorized into three major groups. The list of challenges includes the need for:

1. A comprehensive reference library/database accessible from the desktop, e.g., the ability to search and retrieve science articles and science literature from one's desktop instead of going to the library.
2. Easier access/index to images over the Internet so that one can know what is contained in an image before ordering it or downloading it (e.g., thumbnail sketches of images with explanation of the data contained with each image).
3. High-resolution teleconference capabilities (voice, video and whiteboarding) that are easy to set up and use to eliminate the need to physically travel to other collaborative sites. This capability can be used for lecture presentations, instrument design, project team meetings, etc.
4. Seamless, rapid, distributed access to very large (up to gigabit) datasets with the ability to maintain access control for protection of the data, and also a means to assure that sufficient bandwidth is always there for rapid retrieval and interaction with data. The space exploration community would use this for both active missions such as planetary rovers (when decisions about the rover's next move can be made in relatively short time), and for data analysis of past missions which is considered intellectual property.
5. Increased bandwidth to Mars/Moon to better enable planetary exploration via telerobotics.
6. Data analysis tools and debugging capability that can simultaneously display and overlay 3-D image/hologram datasets and manipulate them on the fly.
7. Improved virtual reality interface (anthropomorphic) to planetary rovers in order to do remote science, and better telepresence control (e.g., the ability to see and control planetary exploration from a different vantage so as to fully explore the planets).
8. Adequate network capability between other planetary systems and Earth to provide broadcast quality for scientifically robust missions.
9. Provision of systems similar to GPS for other planets. One of the difficulties of space exploration and navigation is knowing where you are on a planet.
10. Constellations of satellites around Mars for continuous communications with Earth. If we have human exploration on Mars, the people on Mars will need to be able to communicate with Earth 24 hours a day. That is not possible today because communications between Earth and Mars occur only when the relay point (orbitor) is facing Earth.
11. Data integrity to insure that no packets from space are lost.
12. Seismology measurement networks on Mars.

7.5.4 Conclusion

The twelve brainstorming points were consolidated into three major categories:

7.5.4.1 Category 1: Database Search and Retrieval Index

Items # 1, 2

One of the major hurdles planetary geologists face in their daily work is getting access to scientific journals that are commonly listed in the Scientific Citation Index. Most of the Ames scientists save up quarters and dimes and then head for the Stanford Library to copy the articles needed. This effort takes about 15 to 20 percent of the scientists' time—a grossly inefficient and wasteful way of doing research. These planetary geologists need to be able to access a virtual library at their desktops. Since most of the planetary geologists' work involves understanding the process of Earth, they need to have access to pictorial images of the atmosphere, terrestrial, meteorological events, etc. They need to have thumbnail sketch image indexing prior to downloading the actual image.

7.5.4.2 Category 2: Communications and Analysis Tools via the High Capacity Internet

Items # 3,4,5,6,7

The ability for a planetary geologist to map an Earth event to a 3-D image without having to calculate the 2-D mathematical equations will tremendously improve their understanding and prediction of these events. The knowledge will enable them to understand other planetary systems at much greater efficiency and accuracy. These scientists will also need to communicate and collaborate their findings over the Internet with other scientists. They also need to participate in remote rover operations such Mars Pathfinder, Nomad Rover in Antarctica, JPL Rocky tests, etc., during the mission.

7.5.4.3 Category 3: Planetary Expedition Networks

Items # 8,9,11,12

For any type of manned planetary space exploration, rudimentary communications links need to exist on each planet, such as GPS systems for ground navigation, which could also be used to monitor precise measurements on the surface of the planets, for network science, and for a high capacity communications network for intra- and interplanetary posts.

Even though category 1 deals mainly with content (i.e., digital library), the network connectivity requirement for this type of network could be dealt with on a Class 3 network as defined by NREN[2], such as the NASA Integrated Services Network (NISN). The category 2 requirement is potentially a Class 2 network provided that the type of multimedia applications are being developed to run over OC-3 (155 Mbps) bandwidth. Category 3 requirements call for, at minimum, a Class 2 type network.

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[2] NREN introduced four classes of networks at the workshop. Class 1 is classified a the "bleeding-edge" technology and is possibly a chronically unstable network environment. Class 2 comprises research networks and is classified as a leading-edge technology with more reliability than Class 1. Class 3 covers operational networks using state-of-the art technology attainable in the commercial world. Class 4 covers production networks similar to those in the existing Internet and other similar intranetwork technology.

7.5.4.4 Classification of Applications over NREN

The group established a tentative time frame indicating when the applications discussed above would need advanced networking capabilities. The table below outlines this discussion.

Time	Project Name	Application
1998	Nomad in Antarctica	Category 2 for remote rover operations
1998	JPL Rocky tests	Category 2 for remote rover operations
1998	Mars Global Surveyor	Category 1/2 for Image Database
1998-2000	Space Station	Category 2 for Collaborative Tools
2000	Mars Surveyor	Category 1/2 for Image Database
2001-2005	Mars Rovers	Category 2 for remote rover operations
2011	Human on Mars	Category 3 for PEN

The common element lacking in current and future network applications, therefore, is high performance networking. In fact, the limited communications network between Earth and space has affected the design of the telecommunications and rover operations for planetary explorations such as the Mars Pathfinder mission's rover, Sojourner.

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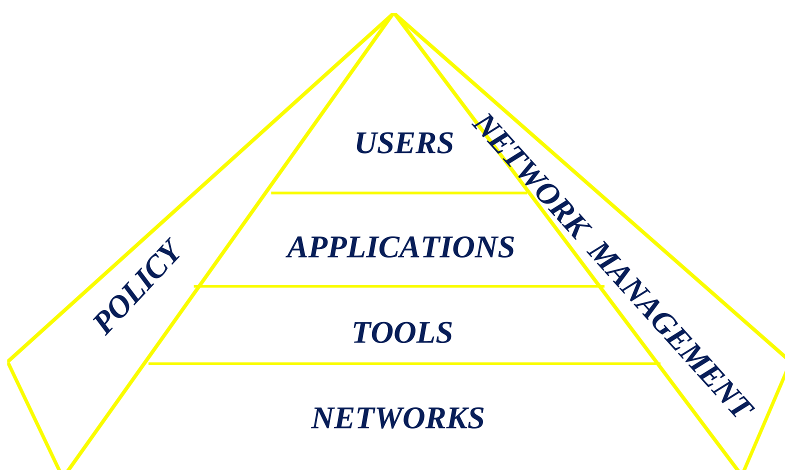
7.6 <u>Telemedicine</u> Affinity Group White Paper



7.6.1 Introduction

The Telemedicine Affinity Group (TAG) met September 17-18, 1997, as part of the second NASA Research and Education Network (NREN) workshop held at Ames Research Center in Mountain View, California. The TAG was chartered with the task of determining key discipline problems and experiments that should be addressed by NREN within the next five years. The group was chaired by Charles Doarn of the NASA Headquarters Office of Life and Microgravity Sciences and Applications (Code UO). Matt Chew Spence of NREN was the designated Network Advisor, and Wanda Luke of the NASA Integrated Services Network (NISN) provided administrative support. An attendee list is provided in appendix A.

The potential of high performance networking is rapidly becoming apparent as new ways to apply advanced networking technologies are realized. One of these applications is in the field of telemedicine—the use of the Internet to share medical information on a global basis for collaboration, education, and assistance in natural disasters. In order to familiarize the affinity group members with the role of telemedicine currently within NASA, copies of the NASA *Integrated Strategic Program Plan For Telemedicine* † were distributed to participants. As the majority of the attendees were in the networking field, and Dr. Dani Goldwater was the only member of the medical community present in the group, it was decided to focus on discipline problems and types of applications that could benefit from NREN research and prototyping rather than to attempt to determine specific future NREN experiments. It was felt that further outreach to the medical community is required to properly determine specifics of this nature.

7.6.2 Challenges Facing Telemedicine

The TAG launched into discussions regarding the challenges facing networked telemedicine over the next five years. The results of that discussion are outlined below.

7.6.2.1 Bandwidth Issues

- Cost of dedicated high speed access
- Network congestion
- Need to dynamically change bandwidth “on the fly”
- Bandwidth needs will only increase as new medical imaging technologies are implemented
- More efficient compression implementation is needed
- Better cost-effective network access is needed for non-backbone and nomadic users
- Need ability to efficiently allocate bandwidth for nonsymmetrical data flows
- Need high capacity bandwidth available on demand

7.6.2.2 Prioritization/Quality of Service Issues

- Ability of network to categorize and prioritize based on instrumentation requirements
- Recognition and determination of real-time versus delayable data
- Ability to maintain quality of service parameters across autonomous systems

† This and other documents about NASA Telemedicine and telemedicine in general can be obtained via the Web from links on the NASA Telemedicine home page at: http://www.it.hq.nasa.gov/~kmorgan/telemed_blue/ welcome.html

7.6.2.3 Heterogeneity across Networks—Handling Method Issues

- Transferring data from one type of workstation to another
- Transferring data between software applications
- Hardware/software interoperability standards needed
- Ability to efficiently share resources such as processing across network

7.6.2.4 Privacy and Security Issues

- Medical data needs to maintain privacy from end to end
- Network needs to be fault tolerant

7.6.3 Experiment/Application Requirements Criteria

After identifying the challenges facing telemedical networking, the group determined the following criteria for use in evaluating the appropriateness of possible future NREN telemedical research and experiments. The research and experiments shall:

- Be necessary to telemedicine
- Have multiple use (depth and breadth)
- Provide a foundation for other capabilities
- Leverage off of other activities rather than re-invent the wheel
- Ensure that the technology implemented matches the requirement
- Ensure that NREN requirements be networking focused

7.6.4 Key Telemedicine Applications

This process began with group members identifying discipline problem areas and possible application areas where NREN could be helpful. The group identified three arenas which could benefit from NREN research and prototyping: Lunar/Planetary Outposts, Education, and Rural Telemedicine. The TAG participants formed three subgroups, each focusing on devising possible telemedicine scenarios for one of the aforementioned arenas. These scenarios are as follows:

7.6.4.1 Scenarios

<u>*Lunar/Planetary Outpost Scenario:*</u>

Requirements:

- High levels of autonomous operation
- Higher level of staff medical training

- Complex integrated local medical information systems
- Enhanced assisted diagnosis and treatment
- Communications security and reliability
- Mirroring of critical information with Mission Control on Earth
- High speed local area network on Moon station
- Distance learning to maintain staff training
- Nomadicity for functions outside of main station
- Virtual environments

Education Scenario:

Single Physician:

- Continuing medical education
- Medical consultation
- Expert systems analysis
- Database and image transfer
- Telemedicine instrument pack
- Bandwidth-on-demand
- Equipment cost
- Transportable
- Virtual university
- Contract with hospital

Emergency Medical Care:

- Wireless telemetry
- Database and image transfer
- Service availability (24 hour/7 days)
- Quality of medical service (always a trauma)
- Restricted bandwidth (mobile)
- Mobile communications
- Integrated services (voice, data, image/video)

Rural Telemedicine (see Appendix B)

7.6.4.2 Areas of Interest

Once the process of drafting scenarios was complete, further discussion resulted in elucidation of the areas of interest summarized below.

1. NETWORKING

Connectivity

- Work with researchers and industry to prototype dependable multiple-priority high speed end-to-end bandwidth available on demand.

- Work with researchers and industry to prototype dependable multiple-priority and/or high speed access from remote and nomadic locations requiring wireless access.

- Intelligent network technologies able to efficiently and dynamically allocate bandwidth. End-to-end Quality of Service (QoS), including appropriate prioritization is a key part of this allocation. The network should be flexible and adaptable enough to efficiently deal with asymmetrical data flows and the differing needs of multiple input/output interactive devices.

- Priority determination above and beyond today's application-based network prioritization schemes. The file transfer of the medical records of someone undergoing a medical emergency should have a higher network transit priority than a routine weekly teleconference, regardless of the technology underlying each application.

- Link major medical research centers such as the Cleveland Clinic and the Commercial Space Center Medical Informatics and Technology at Yale into NREN so as to facilitate telemedicine research and experimentation.

<u>Protocols, Middleware and Foundation Technologies</u>

- Work with researchers developing networking protocols and foundation technologies of use to telemedicine such as new transport protocols, more efficient compression, “Push technologies,” and real-time and reliable multicasting.

- Assist in prototyping of networked systems implementing telemedicine data platform and application interoperability standards, such as emergency medical data standards.

<u>Network Management and Quality of Service (QoS)</u>

- Use capabilities of advanced networking technologies to prototype a networking infrastructure able to provide different levels of network services with differing characteristics to users at appropriate costs.

- Prototype and implement QoS implementations that allow data flows to maintain prioritization and network levels of quality from end to end, even if data flows across multiple carriers and autonomous systems.

- Prototype and implement secure networking testbeds with infrastructures robust enough to withstand failures or intentional attacks, as well as utilizing encryption and/or other security mechanisms to protect data such as medical records.

- Assist in developing and prototyping QoS mechanisms that translate network resource and allocation policies into real-time network behavior and that can capture requested and provided levels of service into full cost accounting systems that charge users appropriately.

2. PROTOTYPING AND INTEGRATION OF HARDWARE AND SOFTWARE SYSTEMS

<u>Networked Instruments and Medical Imaging Display Tools</u>

- Prototype and assist with development of networked medical and lab instruments with capabilities such as: remote real-time data acquisition for patient monitoring; remote instrumentation control and manipulation for diagnosis and research; robotics; and instrumentation with fail-safe/autonomous modes that activate upon loss of networked command and control.

- Prototype and assist with development of alternative “hands-free” user interfaces such as heads-up displays, allowing individuals to access medical data, vital statistics, and decision support systems while performing medical procedures.

- Prototype and assist with development of 3-D tele-immersive multisensory medical imaging display technologies such as holography and haptic interfaces for educational and diagnostic purposes, including virtual travel through body and human genome display.

<u>Medical Database and Server Technology Development</u>

- Assist with research and implementation of networking systems able to provide rapid access to disparate data and video streaming servers containing library, classes, training, and news data in a combination of a variety of forms such as audio/video/image/text on demand.

- Prototype and assist with development of intelligent agents/autonomous agents capable of performing data mining and extraction of relevant information across multiple networked databases such as electronic patient medical records, digital libraries, medical abstracts, imaging data, etc.

<u>Collaboration Support Tools</u>

- Integrate and connect existing systems across disparate hardware platforms, allowing researchers to use virtual systems environments to collaborate and share data in real-time.

- Improve current video-teleconferencing and whiteboard technologies by incorporating tele-immersive and advanced collaborative virtual environments such as CAVEs and ImmersaDesks.

3. POSSIBLE MEDICAL IMPLEMENTATIONS OF NEXT GENERATION TECHNOLOGIES

Clinical/Patient Care

- Use network to provide audio/video monitoring and remote systems operation as necessary to in-home patients. Such multimedia systems could provide for periodic monitoring, allowing for remote electronic “house calls” by nurses, doctors, pharmacists, and mental health professionals. In-home and remote medical equipment should allow for remote command and control as well as incorporate autonomous control systems for when the network link is not active. Equipment should be intelligent enough to initiate connectivity to a medical institution and notify remote medical personnel when the patient needs immediate attention.

- Use of networked resources to provide patient mental stimulation and comfort before, during, and after procedures requiring hospitalization. This might include scenarios such as providing patient telepresence to familiar surroundings during hospital stays, as well as providing content such as news, audio and video on demand.

- Use of networked collaborative virtual medical environments to provide capabilities such as: expert system assisted diagnosis; real-time interoperative peer consulting; remote access to distributed pathology and laboratory devices; remote interactive physical examinations via haptic interfaces; and remote robotic physical exam and surgery.

- Pre-procedure simulation and collaborative planning of surgical operations.

Education

On-demand network access to tele-immersive virtual environments can provide just-in-time training for remote telemedical activities. Simulation of surgical procedures, emergency room situations, and trauma/burn exercises can be used to teach medical students and provide continuing and just-in-time training to medical practitioners in remote locations.

7.6.5 Conclusion

Many of the technologies and research that would be useful to telemedicine in the next five years mirror the general NGI topics described in the white papers within the publication *Research Challenges for the Next Generation Internet*[††]. The question is how to best apply these network and networkable technologies to meet telemedicine challenges. Increased representation from the telemedicine and general medical communities would also greatly assist in determining how NREN can best be of assistance in furthering agency and governmental telemedicine requirements.

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Appendix B - Rural Telemedicine Scenario

(* denote technologies or network/system features involved)

Features: Ease of use; wireless and mobile "nomadic" communications, access and connectivity; dynamic instantaneous ("ad hoc") network setup, "awareness" and capacity; crossplatform interoperability; distributed access to specialized databases and medical devices as nodes on network; Electronic Medical Record (EMR); wireless telemetry; database and image transfer; integrated services (voice, data, image, video); 24-hour service availability; private secure access.

• 1) Young father develops cough, severe chest pain, trouble breathing, fever. Ambulance called to rural home. Helicopter unavailable.

• 2) Paramedics start oxygen, insert IV line, hook up to cardiac monitor, load patient into ambulance. Nearest rural hospital 80 miles away. Big city general hospital over 200 mi. away. Paramedics confused since presentation somewhat atypical for heart attack with low voltage on ECG, strange cardiac waveform complexes on monitor, arrhythmia, plus multifocal premature ventricular contractions. Patient is in acute distress.

* Computer system onboard ambulance activated. Network request issued for on-demand satellite-based system where ambulance becomes node on Internet

[††] Available in Adobe Acrobat format via the Web at: http://www.cra.org/main/cra.pubs.html

assigned network address (www.ambulance2.help) to provide with distributed access on demand to monitoring devices and audio/video outputs (www.ambulance2.help/ecg). Secure, high priority, assured delivery connection established.

• 3) Initial contact made to rural hospital. ECG and vital signs (Temp, BP, HR, respirations) transmitted with high resolution color video of patient. Nurse practitioner on duty. General Practitioner can be called in if needed. Nurse detects skin is bluish (cyanotic) and asks paramedics to increase oxygen flow rate and make sure airway is clear. Nurse retrieves patient's electronic medical record (EMR) from Web and downloads patient's most recent prior ECG and relevant history. Current ECG shows marked change from routine ECG test three months ago. Nurse calls up the atypical chest pain clinical algorithm (protocol) and makes a decision to contact cardiologist on-remote-call from Big City General (Cleveland Clinic).

* wireless telemetry

* Web-based electronic medical record

* data mining and extraction

* assisted decision-making (clinical pathways)

• 4) Dr. James Thomas, Cleveland Clinic cardiologist happens to be playing golf (17th hole) when his beeper goes off. He opens up his pocket HP notebook computer and receives the message along with real-time videoconferencing with the rural hospital nurse and the ambulance. The relevant patient past medical history is downloaded together with the most recent ECG and the current ambulance ECG, vital signs and video. Dr. Thomas views the current and past data side by side, requests and receives additional data including cardiac and chest auscultation via electronic stethoscope, digital chest x-ray and ultrasound cardiac output. He tells the paramedics to administer an antiarrhythmic agent, and he watches the effect on the ECG while the patient receives it by intravenous push.

• 5) He accesses a cardiology database and double checks the statistical probabilities on the differential diagnoses he is considering, then tells the paramedics to also begin anti-inflammatory medications. He then pages a colleague who is an infectious disease expert at the Center for Disease Control (CDC) in Atlanta to discuss his suspected diagnosis—infectious myocarditis. After the discussion, Dr. Thomas double checks with the patient and consults the EMR regarding allergies. He then asks the paramedics to collect sputum and urine cultures en route, draw blood for cardiac enzymes, and asks the nurse to draw sterile blood cultures and administer broad spectrum antibiotics as soon as the patient reaches the hospital. He resumes play on 17th hole, but asks the paramedics to update him on the patient's vital signs and progress every 15 minutes or more frequently as needed.

* "curbside" remote tertiary medical consult

• 6) The paramedics access a proprietary network ambulance service Web database regarding proper collection technique and storage of the various patient specimens while en route. The database is tailored for their emergency vehicle and equipment stowage configuration.

• 7) Meanwhile, the CDC expert links with the rural hospital nurse and instructs her on isolation preparations and infection control arrangements for the patient's arrival and hospital stay. He also tags the patient's EMR and instructs his intelligent Web navigator to update the CDC epidemiological files with the results of the patient's medical studies.

• 8) Virtual Family Visits for patient comfort and facilitation of healing: The patient's isolation precautions prevent family visits during the first ten days of his long hospital stay. The stress of separation from his wife and young children threatens his medical progress. The nomadic camera system is deployed over NREN enabling real time audiovisual interaction with his family from his hospital bed.

* Panospheric camera provides continuous 360-degree views of his home at real-time video speeds. Full audio channel.

* Robotic or portable camera can be moved room to room as needed.

* Patient can control "dewarped" view or camera orientation by joy-stick from his bed.

* Two-way link

* Image processing done at NASA Ames (see diagram)

**Testbeds—hospitalized children separated from parents and families

**Space Applications—astronauts on long-duration missions or Mir Space Station, separated from families; virtual Mars mission immersive environment for earthlings.

• 9) After acute infectious stage, patient discharged for home monitoring of chronic congestive heart failure while he awaits cardiac transplant. Some variables are continuously monitored and aberrant values are transmitted with alerts to his nurse case manager or physician. Routine information is transmitted to the EMR daily or weekly, such as: temperature, weight, fluid intake and output, activity level, heart rates, ecg rhythm, oxygen level, skin color, peripheral edema (ankle swelling), neck vein engorgement, etc. Trend analysis is automatically done on the data.

• 10) The virtual visiting nurse program is implemented, with more detailed examinations and real time videoconferencing once per week. The nurse coaches the patient through his periodic ultrasound cardiac exam to make sure the necessary updates are of sufficient quality for calculations of cardiac output, ejection fraction, chamber size, etc. Medications, exercise and nutrition are adjusted as necessary.

• 11) The patient has 24-hour access to networked medical care from his home computing devices, including emergency pages and conferencing. He can leave an email, voice or video messages for his health care providers at any time and he knows he will be answered promptly.

• 12) Informed health care consumer: To encourage true partnership in his own medical care, this patient has full access to his EMR, to bibliographies, and to special research and clinical databases regarding his disorder. If he wants a second opinion, he can send the access code for his full EMR, or subsets, e.g., his cardiac biopsy slides or 4-D ultrasound to the telecardiologist of his choice (for a fee). He is notified automatically via his Web browser agent of new experimental drug studies or device protocols sponsored by the NIH, NHLBI or FDA. He can also check to see where he is currently on the transplant waiting list. He frequently accesses his interactive educational and rehabilitation programs for dietary and exercise advice. He and his family also interact through video chat rooms with other families in the same boat.

8. CONCLUSIONS

The NASA scientific community is developing applications and tools that require increasingly sophisticated and powerful networking capabilities to support such activities as collaboratories, data visualization, remote control of instruments and rovers, telepresence, data access and retrieval, distributed interdisciplinary modeling, and mobile applications. NREN's challenge for the future will be to ensure that network performance provides high bandwidth, high speed, and high capacity and at the same time provide reliable, responsive services to a heterogeneous community of platforms and users.

The Workshop affinity groups categorized network priorities and challenges, functional areas, and application areas somewhat differently, and there is inherently some overlap in the categories. However, the broad scope of the groups' overall requirements and concerns paints a vivid picture of next generation scientific networking requirements that pose a challenge for the networking community.

8.1 Analysis

The reports of the Workshop Affinity Groups were analyzed first by doing a "bottoms-up" analysis of each report, then by doing a "cross-cut" synthesis across all the bottoms-up analyses to create a summary. The summary results are presented first, in three groups: specific applications, generic applications, and network capabilities. This summary constitutes the starting point for development of the "so what?" from the Workshop.

A more narrative prioritized and annotated list will be prepared of each of the above groups, then validated against reports by telephone interviews with the affinity group chairs. This narrative "NREN Discipline Affinity Group Needs" list will be distributed via email back to the affinity groups for their comments, then a final draft of the summary and conclusions will be prepared based on the comments received. This draft detailed plan will also be the subject of a follow-on Workshop to kick off the next phase of work of the NREN affinity groups.

8.2 Summary: Combined Needs

8.2.1 Specific Applications:

<u>Telepresent robotics</u>:	<u>Section</u>
AB Telepresent robotics	7.2.5.1

AP Telepresent operation of mobile robots	7.3.3.5
SE Remote rovers: Antarctica, JPL, Mars	7.5.3; 7.5.4.4
<u>Remote instrument operation and telecollaboration</u>:	<u>Section</u>
AB Remote instrument operation and telecollaboration	7.2.5.2
AP Telescope remote control	7.3.3.1
ES Instrument Support Terminals	7.4.2
<u>Discipline-unique</u>:	<u>Section</u>
AD Design environments	7.1.3.1
AD Information Power Grid	7.1.3.2
See also: computational resource structure	7.1.4.2
and massively parallel inefficient peering	7.1.5
AD Wind tunnels and simulators	7.1.3.2
AD Physics-based deep analysis	7.1.3.3
AP Coordinated, multispectral, multisite observation	7.3.3.4
ES Distributed Image SpreadSheet and other visualization tools	7.4.2; 7.4.3; 7.4.4; 7.4.5
ES Quality assurance of data products	7.4.2
ES Critical real-time applications (e.g. severe weather warnings; disaster response, monitoring and mitigation)	7.4.2.2
ES Climate modeling	7.4.4
ES Atmosphere and weather modeling	7.4.4
ES Earth resources assessment	7.4.4
SE Planetary Expedition Networks (PENs) (intraplanetary)	7.5.2; 7.5.3; 7.5.4
SE High performance networks to planetary outposts (interplanetary)	7.5.1; 7.5.2; 7.5.4.3
TM Telemedicine to lunar/planetary outposts	7.6.4.1
TM Medical education	7.6.4.1; 7.6.4.2 (#3)
TM Rural telemedicine	7.6.4 (and App. B)
TM Clinical/patient care	7.6.4.2 (#3)
TM Telemedicine data platform and applications interoperability standards	7.6.4.2 (#1)
TM Networked telemedical instruments and imaging displays	7.6.4.2 (#2)

8.2.2 Generic Applications:

Collaboration:	Section
AD Distributed collaboration	7.1.4.1
AB Distributed collaboration	7.2.1
AP Distributed collaboration	7.3.3.3
ES Collaboratories	7.4.3
TM Telemedicine collaboration support	7.6.4.2 (#2)
Distributed processing, modeling, analysis and visualization:	Section
AD Information visualization and analysis distributed environment	7.1.4.3
AB Distributed processing and modeling	7.2.5.3
see also: ability to incorporate multiple data and media types independent of platform	7.5.4.4
AP Distributed collaborative computing (similar to distributed processing and modeling in Astrobiology)	7.3.3.1
ES Distributed interdisciplinary modeling	7.4.4
SE 3D/VR analysis collaborative tools	7.5.4.2
Data life cycle:	Section
AP Observation and collection of data	7.3.3.1
AP Data distribution: Archival, analysis, understanding	7.3.3.1
AP Data dissemination: Education and outreach	7.3.3.1
ES Data dissemination to researchers	7.3.3
ES Educational outreach	7.3.2
ES Remote access to data and information	7.4.3; 7.4.4; 7.4.5
ES Distributed digital libraries	7.4.3; 7.4.5
SE Digital library access	7.5.4.1
ES Intelligent data discovery	7.4.5
Nomadic applications:	Section
ES Mobile applications	7.4.5
TM Nomadic and wireless access	7.6.4.2
Applications technologies:	Section
ES Distributed time stamping (not needed with GPS?)	7.4.2.3
TM Efficient compression and new transport protocols to minimize end-to-end delays for high priority images (e.g., telemedicine, disaster)	7.6.4.2 (#1)
AD Virtual file cabinets and storage	7.1.5

8.2.3 Network Capabilities:

NOTE: Network capabilities needed by AP and SE were not stated explicitly, but it may be inferred from their applications that, with the exception of network capabilities unique to planetary networks (covered under the heading of Discipline-unique Specific Applications), AP and SE needs are covered by the list below.

Classes and qualities of differentiated service at appropriate costs:	Section
AD guaranteed performance and predictability	7.1.5
ES QoS: latency, delay, low error rates, reservation, prioritization, classes of service	7.4.2
TM end-to-end QoS across multiple carriers and autonomous systems including bandwidth on demand and prioritization of data flows	7.6.4.2 (#1)
TM differentiated services at appropriate costs	7.6.4.2 (#1)
TM network resource and allocation policies translated into requested network services with appropriate cost accounting and billing	7.6.4.2 (#1)

Security:	Section
AD security	7.1.5
ES security	7.4.2
TM security	7.6.4.2 (#1)
AB security of proprietary and predecisional data	7.2.5.4
AD 'process antibodies' (protection systems built into the network)	7.1.5

Multicast and push:	Section
AD multicast and push	7.1.5
TM reliable multicast and push	7.6.4.2 (#1)
ES reliable multicast	7.4.2.2

Network characteristics and services:	Section
AD nomadic users	7.1.5
ES switched virtual circuits	7.4.2.
AD scalability	7.1.5
AD standard peripheral interfaces	7.1.5
AD network management	7.1.5
AD heterogeneous networks	7.1.5
AB instrument and network/session integrity	7.2.5.4
AB network reliability for instrument command and control	7.2.5.4
AB effective and responsive bandwidth for remote human collaboration	7.2.5.4
AB backward compatibility to existing Internet	7.2.6
ES multimedia	7.4.2.1

ES administration and accounting	7.4.2.1
AD billing for network services	7.1.5
Connectivity (Goal 2):	Section
AD extended reach and connectivity	7.1.5
ES connectivity to other networks (e.g., Internet2)	7.4.2.2
ES international connectivity (e.g., Japan, Germany)	7.4.2.2

8.3 Summary: Individual Affinity Groups

8.3.1 Aerospace Design—AD

Specific Applications:

Design environments

Information Power Grid

also see computational resource structure

and massively parallel inefficient peering

Wind tunnels and simulators

Physics-based deep analysis

Generic Applications:

1st priority:

-- Distributed collaboration

-- Information visualization and analysis distributed environment

2nd priority:

-- Virtual file cabinets and storage

Network Capabilities:

1st priority:

-- Guaranteed performance and predictability

-- Security

-- Network management

-- Heterogeneous networks

-- Multicast and push

-- Nomadic users

2nd priority:

-- Billing for network services

-- Scalability

-- Standard peripheral interfaces

-- 'Process antibodies' (protection systems built into the network)

-- Extended reach and connectivity

8.3.2 Astrobiology—AB

Specific Applications:

-- Telepresent robotics

-- Remote instrument operation and telecollaboration

Generic Applications:

-- Distributed processing and modeling
(also see ability to incorporate multiple data and
media types independent of platform)

-- Distributed collaboration

Network Capabilities:

-- Instrument and network/session integrity

-- Network reliability for instrument command and control

-- Security of proprietary and predecisional data

-- Effective and responsive bandwidth for remote human collaboration

-- Backward compatibility to existing Internet

8.3.3 Astrophysics—AP

Specific Applications:

-- Coordinated, multispectral, multisite observation

-- Telepresent operation of mobile robots

-- Telescope remote control

Generic Applications:

-- Observation and collection of data

-- Data distribution: Archival, analysis, understanding

-- Data dissemination: Education and outreach

-- Distributed collaborative computing (similar to distributed
processing and modeling in Astrobiology)

-- Distributed collaboration

Network Capabilities:

(not broken out specifically)

8.3.4 Earth Sciences—ES

Specific Applications:

-- Distributed Image SpreadSheet and other visualization tools

-- Quality assurance of data products

-- Instrument Support Terminals

-- Critical real-time applications (e.g. severe weather warnings; disaster response, monitoring and mitigation)

-- Climate modeling

-- Atmosphere and weather modeling

-- Earth resources assessment

Generic Applications:

-- Intelligent data discovery

-- Remote access to data and information

-- Distributed interdisciplinary modeling

-- Collaboratories

-- Educational outreach

-- Data dissemination to researchers

-- Distributed digital libraries

-- Mobile applications

-- Distributed time stamping (not needed with GPS?)

Network Capabilities:

-- QoS: latency, delay, low error rates, reservation, prioritization, classes of service

-- Security

-- Switched virtual circuits

-- Reliable multicast

-- Multimedia

-- Administration and accounting

Goal 2 (connectivity):

-- Connectivity to other networks (e.g., Internet2)

-- International connectivity (e.g., Japan, Germany)

8.3.5 Space Exploration (Planetary)—SE

Specific Applications:

-- Planetary Expedition Networks (PENs) (intraplanetary)

-- High performance networks to planetary outposts (interplanetary)

-- Remote rovers: Antarctica, JPL, Mars

Generic Applications:

-- Digital library access

-- 3D/VR analysis collaborative tools

Network Capabilities:

(not broken out specifically)

8.3.6 Telemedicine—TM

Specific Applications:

-- Telemedicine to lunar/planetary outposts

-- Medical education

-- Rural telemedicine (also Appendix B)

-- Clinical/patient care

-- Telemedicine data platform and applications interoperability standards

-- Networked telemedical instruments and imaging displays

Generic Applications:

-- Telemedicine collaboration support

-- Nomadic and wireless access

-- Efficient compression and new transport protocols to minimize end-to-end delays for high priority images (e.g. telemedicine, disaster)

Network Capabilities:

-- End-to-end QoS across multiple carriers and autonomous systems including bandwidth on demand and prioritization of data flows

-- Reliable multicast and push

-- Differentiated services at appropriate costs

-- Security

-- Network resource and allocation policies translated into requested network services with appropriate cost accounting and billing

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